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The Canadian Entomologist

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The Canadian Entomologist

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Responses to Light and Influence of Light and Temperature on Locomotion of the Crawler of the Balsam Woolly Aphid, *Adelges piceae* (Ratz.) (Homoptera: Phylloxeridae), and of Insect Predators of this Species[1]

By B. C. Smith[2]
Entomology Laboratory, Belleville, Ontario

This is a report on observations made in the field and in the laboratory in 1954 and 1955 at Fredericton, New Brunswick, on the responses to light and influences of light and temperature on the locomotory activities of introduced insect predators and the motile first-instar larva, or crawler, of the balsam woolly aphid, *Adelges piceae* (Ratz.). Adults and larvae of the predators were observed in the field and tests were conducted with adults in the laboratory. The species studied were *Aphidecta obliterata* (L.) and *Pullus impexus* (Muls.) (Coleoptera: Coccinellidae), *Cremifania nigrocellulata* Cz. and *Neoleucopis obscura* (Hal.) (Diptera: Chamaemyiidae), and *Laricobius erichsonii* Rosenh. (Coleoptera: Derodontidae). The work is part of an investigation on factors influencing the searching abilities of the predators.

Materials and Methods

Adults and larvae of the predatory species were obtained from the release areas (Smith and Coppel, in preparation) near Fredericton.

In the Field

Groups of at least 25 last-instar larvae of *A. obliterata, C. nigrocellulata, L. erichsonii,* and *P. impexus* were observed in field cages each enclosing approximately 800 square inches of bark and of the type described by the author (in preparation), the larvae being confined on trunks of trees heavily infested with *A. piceae.* Each prey-infested bark surface was divided into square-inch sections to make it easier to follow the movements of the predatory larvae. The larvae of each species were observed during two days, the various species being observed at different times. At intervals of 30 minutes between 9.00 a.m. and midnight, a marked insect pin was inserted in the bark behind each larva and the larva was recorded as moving, feeding, or stationary. A flashlight was used to locate the larvae in darkness; this light did not greatly influence the activities of the larvae because they were exposed to it only for short periods. At the beginning and end of each observation the air temperature, relative humidity, and light intensity within the cage were recorded, and averages were taken as representative of these conditions during the period of observation. Before the pins were removed, the distances between them were measured to find the minimum distance moved by each larva in the 30-minute period.

In the Laboratory

Tests were conducted in three cold-storage rooms providing air temperatures of 0°C. to approximately 15°C. and relative humidities of 65 to 80 per cent, and in another room without windows at approximately 25°C. and a relative humidity of 55 to 65 per cent. In this room a temperature increasing from 20° to 45°C. at a relative humidity of approximately 25 per cent was obtained in a cylindrical cage placed over an electric heater. A rectangular cage and an octagonal cage were used at temperatures from 0° to 25°C.

[1]Contribution No. 3700, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.
[2]Assistant Entomologist.

The cylindrical cage consisted of a white cardboard container 7.6 cm. wide and 1.3 cm. deep. Plastic screen covers were fitted to the top and bottom of the container, which was placed on a copper plate with an electric element attached to its lower surface. The air temperature within the container was read from two thermometers, one with its bulb near the top and the other with its bulb near the bottom. The average of the two readings was taken as representative of the air temperature within the container.

The rectangular cage was 45 cm. long, 22 cm. wide, and 30 cm. high. The top and sides were of fine-mesh plastic screen, the front of transparent plastic, and the floor of Masonite (International Fiberboard and Plywood Company, Gatineau, Quebec).

The octagonal cage, which was constructed of one-eighth-inch plate glass, was symmetrical and had two sides 47 cm. long, two sides 7 cm. long, and four sides 13 cm. long. The cage was 1.5 cm. deep, the top being detachable, the floor transluscent, and the inner surface roughened to reduce the glaze. The air temperature within the cage was read from two thermometers inserted through holes in the end walls, and the average of the two readings was taken as representative of the temperature within the cage.

The light sources used in the tests were incandescent filament-type lamps of various wattages (Canadian General Electric Company, Toronto, Ontario) and a microscope lamp (American Optical Company, Buffalo, New York). The light intensity of the microscope lamp was changed by adjusting the potentiometer control of the lamp, which was calibrated to give relative light intensities of 25, 200, and 800. Light intensity was measured with a Weston Master II exposure meter (Weston Electrical Instrument Corporation, Newark, New Jersey). The crawler of *A. piceae* was observed with a Zeiss Opton microscope at a magnification of X25.

Details of the investigations are as follows.

High Temperature.—Three-week-old adults of *L. erichsonii* and *P. impexus* and two-week-old adults of *N. obscura* were exposed to light at a temperature increasing from 20° to 45°C. They were kept at 20°C. and without food for two days preceding the tests, which were conducted in the cylindrical cage. A small area of the cage was illuminated from above by a narrow beam of the highest light intensity from the microscope lamp. In a test 20 insects were released in the cage and closely observed for 30 minutes, during which time the temperature rose approximately one degree per minute. The activities of the insects were noted at one-minute intervals. One test was made with each species.

Direct Light.—Newly emerged adults of *A. obliterata* and five-day-old adults kept without food under field conditions were exposed at 25°C. and 65 per cent relative humidity to three intensities of white light from lamps of 7.5, 60, and 150 watts with relative intensities of 22, 180, and 450. A lamp was placed 66 cm. from one end of the rectangular cage, the floor of which was divided by two chalk lines into three equal areas. In each test 10 insects were released in the central section, and after three minutes their distribution in the three sections of the cage was recorded. There were three replications for insects from both age groups at each light intensity. Tests with light were alternated with tests in the absence of light.

Seven-day-old adults of *L. erichsonii* and *N. obscura* kept without food for 24 hours, and 30-day-old adults of *P. impexus* similarly treated,, were exposed in the rectangular cage to white light from a lamp of 7.5 watts at 12° and

20°C. The same procedure was followed here as described for *A. obliterata*. The insects were allowed to adjust to the temperature conditions of the tests for 24 hours preceding the tests, and the same insects were used at both temperatures.

Indirect Light.—Three-week-old adults of *A. obliterata* and *P. impexus* and one-week-old adults of *L. erichsonii*, kept without food in darkness at 4°C. for three days preceding the tests, were observed in the octagonal cage, of which part was illuminated from below by the microscope lamp. The cage was supported 25 cm. from the top of the laboratory table by a stand, and a narrow beam of light was arranged to shine up through the centre of the glass floor at a point 10 cm. from one of the 7 cm. sides. A black disc was placed on the top of the cage opposite the light to reduce reflection. In a test 10 insects were released 10 cm. from the other 7 cm. side of the cage approximately 45 cm. from the point where the light entered. The light was switched on and 10 minutes allowed for the insects to disperse. Then the position of each insect was plotted on the cover of the cage, and its distance from the light was measured. At least three replications were made with each species at the three light intensities of the microscope lamp, and tests with light were alternated with tests without light. Adults of *L. erichsonii* and *P. impexus* were tested at temperatures of 13°C. and approximately 23°C. and *A. obliterata* at 20°C.

Locomotion.—Adults of *A. obliterata* from two groups, one kept at 4°C. without food in darkness for seven days preceding the tests and the other kept under field temperature conditions but otherwise similar conditions, were exposed in the octagonal cage at 25°C. to two intensities of white light from lamps of 7.5 and 150 watts with relative intensities of 22 and 450. The cage was mounted on a wooden housing and illuminated from below by a lamp placed 87 cm. from the bottom of the cage, which had a piece of white drawing paper as a filter between the bottom and the housing. The insects were given 30 minutes to adjust to temperature conditions and five minutes to adjust to conditions of the cage before the tests. Five insects from each group were observed individually at both light intensities. In each five-minute test the path of the insect was traced on the glass cover of the cage, and the number and durations of stops and flight were recorded. On completion of a test, the insect's path was recorded, and the cage cover wiped clean for the next test. Averages of the percentage of time spent walking and flying and of walking rates, determined by dividing the distance walked by the time spent in walking, were calculated for the two groups.

Four-day-old adults of *C. nigrocellulata*, *L. erichsonii*, and *N. obscura*, and 30-day-old adults of *P. impexus*, were exposed to two contrasting light intensities in the octagonal cage at $3.25\pm3°$, $9.75\pm3°$, $16.25\pm3°$, and $22.75\pm3°$C. They were kept without food and in darkness at 4°C. for three days preceding the tests. The procedure used was as described for *A. obliterata* with the following modifications. The low-intensity light was from a 7.5-watt lamp used with blue and red filters, and the relative intensities of the two light sources were five and 450. The same three adults of each species were observed at the various temperatures at both light intensities. Averages of the percentages of time spent walking and flying by the three adults, of walking rates, of frequencies of stopping, and of frequencies of path-crossing, were calculated for the four species at each temperature at both light intensities. Frequencies of stopping and path-crossing were expressed on a basis of the number of occurrences per 10 cm. of distance walked.

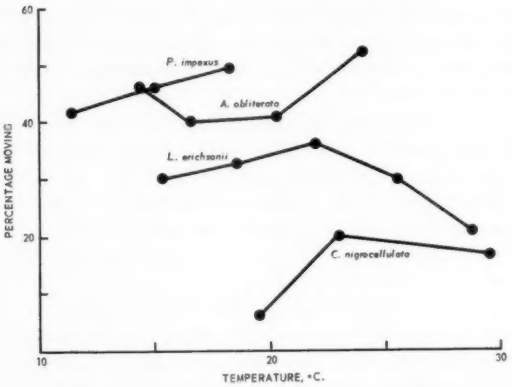

Fig. 1. Percentages of last-instar larvae of *Aphidecta obliterata, Cremifania nigrocellulata, Laricobius erichsonii,* and *Pullus impexus* moving in the field at various air temperatures.

Crawlers of the aestivosistens generation of *A. piceae* were exposed on a piece of frosted plate glass six inches square to relative light intensities of 25 and 800 from the microscope lamp at air temperatures of 10.0°, 16.3°, and 25.5°C. In each test the time taken by the crawler to traverse a diameter of the microscope field was noted, and the walking rate was calculated from this. Sixty crawlers were used in the tests, 20 at each temperature and 10 at each light intensity. Five tests were carried out with each crawler.

Results

In the Field

Adults of *Cremifania nigrocellulata* and *Neoleucopis obscura* made short flights to areas of sunlight at temperatures ranging from 15° to 25°C. However, adults of *Aphidecta obliterata, Laricobius erichsonii,* and *Pullus impexus* were not often observed in flight, but were usually stationary or walked on the bark. These three species walked at temperatures of 8° to 25°C., and they did not appear to be strongly attracted to light. The newly emerged adults avoided high-intensity light, whereas the feeding adults were weakly attracted.

Differences in the distributions of the species on the square-inch sections in the cages provided a basis for a general comparison of locomotion of the larvae at high prey density. The percentages of the sections in which *A. obliterata, C. nigrocellulata, L. erichsonii,* and *P. impexus* were found at some time during the two days of observation were 24, 9, 11, and 51 respectively. *C. nigrocellulata* and *L. erichsonii* remained in the sections in which they were feeding as long as food was present. *P. impexus* preferred the highest sections, whereas the distribution of *A. obliterata* was random. None of the species preferred sections where the density of *A. piceae* was highest, and all species fed during the hours of darkness. The average percentages of *A. obliterata, C. nigrocellulata, L. erichsonii,* and *P. impexus* in movement at any one time between 9.00 a.m. and 7.00 p.m. were 45, 15, 30, and 45 respectively, and the corresponding distances moved were 3.12, 1.67, 1.36, and 5.33 cm. Air temperature appeared to exercise a greater influence on both the number of larvae in movement (Fig. 1) and the distance moved (Fig. 2) than either relative humidity or light intensity.

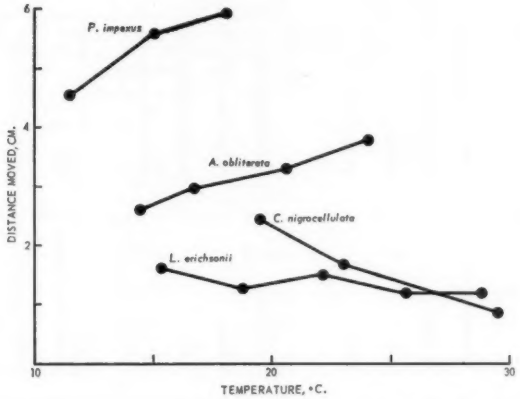

Fig. 2. Average distances moved in 30 minutes in the field by last-instar larvae of four predators at various air temperatures.

Temperature appeared to exercise a greater influence on the feeding of *L. erichsonii* than on that of *C. nigrocellulata*. Of the 70 per cent of *L. erichsonii* not moving at any one time, 40 per cent were feeding and 30 per cent were not. At 22°C. the percentage of this species feeding was 55; at 29°C., 33. The majority of *C. nigrocellulata* not in movement were feeding, and on the average not more than five per cent of this species were stationary on the bark.

In the Laboratory

High Temperature.—During exposure to high temperatures, *L. erichsonii* was indifferent to light; the chief activity was rapid walking, there being few flights. Fifty per cent mortality occurred at 35.5°C. There was little mortality of *N. obscura* at 29° to 36°C. Here the chief activity was vigorous flight, and the adults were photopositive. Between 37.2° and 42.2°C. activity was greatly reduced and the adults were photonegative. Fifty per cent mortality occurred at 40.5°C. *P. impexus* was less active than the other species and its response to light not consistent; 50 per cent mortality occurred at a temperature of approximately 43°C.

Direct Light.—The newly emerged adults of *A. obliterata* were less active than five-day-old adults. They were not attracted by any of the light intensities used whereas the five-day-old adults were weakly attracted. Twelve, 30, and 24 per cent more of the latter group entered the photopositive section of the cage than the photonegative section at the respective light intensities of 22, 180, and 450.

L. erichsonii and *N. obscura* were more active at 20°C. than at 12°C., but *P. impexus* was more active at 12°C. than at 20°C. In the absence of light an average of 50 per cent more adults of *L. erichsonii* and 34 per cent more of *N. obscura* left the release section of the cage at 20°C. than at 12°C., whereas 22 per cent more of *P. impexus* left the release section at 12°C. than at 20°C. In the presence of light the average distributions of adults in the three sections of the cage indicated that *L. erichsonii* was indifferent to light at 12°C. and was repelled at 22°C.; *P. impexus* was repelled at both temperatures; and *N. obscura* was attracted at both temperatures, an average of 20 per cent more adults of

TABLE I

Average distances in centimeters of predatory adults from point of entry of light when exposed 10 minutes in a glass cage to relative light intensities of 0, 25, 200, and 800 at various temperatures (+, toward light; −, away from light)

Species	Temperature °C.	Light Intensity			
		0	25	200	800
Aphidecta obliterata	20	23.5	+11.8	+11.3	+10.6
Laricobius erichsonii	13	24.0	+20.3	+21.4	−25.9
Laricobius erichsonii	23	25.4	−27.7	+24.4	−32.0
Pullus impexus	13	21.6	+16.8	+17.3	+13.7
Pullus impexus	24	27.2	+22.1	+16.2	+12.9

this species entering the photopositive section than the photonegative section at 12°C., and all entering the photopositive section at 20°C.

Indirect Light.—In the majority of tests the average distances of the insects, except *L. erichsonii*, from the point of entry of the light were less than the averages for the tests in the absence of light (Table I). *A. obliterata* and *P. impexus* were attracted by low and intermediate intensity lights and strongly attracted by the high intensity light. The majority of the tests with *L. erichsonii* were not conclusive; this species was repelled by the high intensity light at 23°C.

Locomotion.—Adults of *A. obliterata* kept in the field under varying conditions of temperature were more active and had higher walking rates than those kept at 4°C. in the laboratory. Field adults walked and flew an average of 41 per cent of the time when exposed to the 7.5-watt lamp and 32 per cent of the time when exposed to the 150-watt lamp; the respective walking rates were 24 and 28 cm. per minute. The corresponding figures for adults kept at 4°C. were four and 16 per cent and 9 and 9 cm. per minute.

Adults of *C. nigrocellulata*, *L. erichsonii*, *N. obscura*, and *P. impexus* walked more often than they flew in the octagonal cage. *C. nigrocellulata* and *P. impexus* flew only at high light intensity, the former at approximately 6° to 26°C. and the latter at approximately 19° to 26°C. *L. erichsonii* and *N. obscura* flew at both light intensities at approximately 17° to 25°C. *C. nigrocellulata* was more active at low light intensity than at high up to 19°C. (Fig. 3, A), whereas at the same temperatures *N. obscura* was more active at high light intensity than at low (Fig. 3, C). *C. nigrocellulata* was less active than *N. obscura* at both light intensities near 22°C. *L. erichsonii* and *P. impexus* maintained high levels of activity at all temperatures (Fig 3, B and D), and *L. erichsonii* was regularly more active at low light intensity than at high.

The walking rates of the four species except *C. nigrocellulata* were not affected by light intensity and were higher at the higher temperatures (Fig. 3, E to H). At low light intensity *C. nigrocellulata* had higher rates at the higher temperatures, but at high light intensity the rate did not increase with temperature. With few exceptions the walking rates of both *C. nigrocellulata* and *N. obscura* were greater than those of *L. erichsonii* and *P. impexus* at both light intensities and all temperatures.

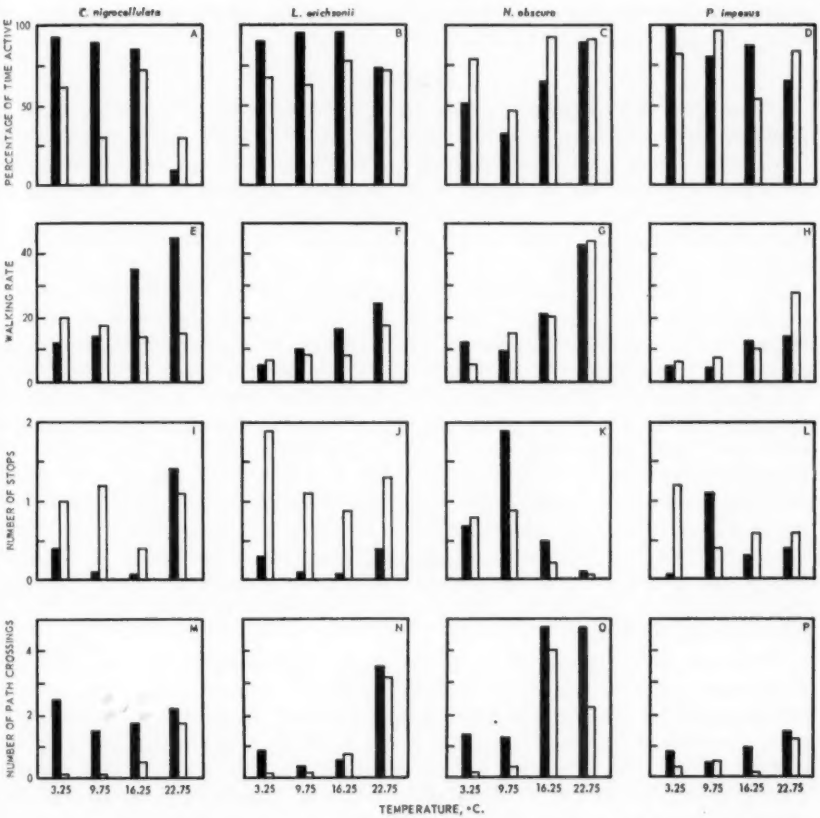

Fig. 3. Average values for percentage of time spent walking and flying, for walking rate, for frequency of stopping, and for frequency of path-crossing for three adults of each of *C. nigrocellulata*, *L. erichsonii*, *Neoleucopis obscura*, and *P. impexus* in the laboratory at relative light intensities of 5 (approximately 0.3 foot candles, solid bars) and 450 (approximately 25.0 foot candles, open bars) and temperatures of 3.25 ± 3°, 9.75 ± 3°, 16.25 ± 3°, and 22.75 ± 3°. A-D, Percentages of time spent walking and flying. E-H, Walking rates in centimeters per minute. I-L, Numbers of stops per 10 cm. of distance walked. M-P, Numbers of path-crossings per 10 cm. of distance walked.

Frequency of stopping was generally greater for *C. nigrocellulata*, *L. erichsonii*, and *P. impexus* at high light intensity than at low (Fig. 3, I, J, and L). This was not observed for *N. obscura* (Fig. 3, K). Frequency of stopping did not appear to be influenced by temperature.

Frequency of path-crossing was appreciably lower at high light intensity than at low for *C. nigrocellulata* (Fig. 3, M). This fact was also observed for *L. erichsonii*, *N. obscura*, and *P. impexus* (Fig. 3, N to P), but was less pronounced in *L. erichsonii* and *P. impexus* than in *C. nigrocellulata* and *N. obscura*.

The walking rate of the crawler of *A. piceae* was greater at high light intensity than at low, and increased with temperature. At the relative light intensities of 800 and 25 the corresponding rates were: 0.276 and 0.234 cm. per

minute at 10.0°C., 0.863 and 0.592 cm. per minute at 16.3°C., and 1.23 and 0.997 cm. per minute at 25.5°C.

Discussion

Adults of the predatory species are more difficult than the larvae to compare systematically with respect to the influences of light and temperature on locomotion under field conditions, as the adults are less numerous and engage in a greater variety of activity. Though the investigations on adults in the laboratory provided a basis for comparing species with respect to light and temperature relations, under these circumstances the insects were exposed to simplified conditions that do not occur in nature. Though it is possible to collect adults in adequate numbers, standardization of insects for testing in the laboratory is a problem. The responses of *A. obliterata*, *L. erichsonii*, and *P. impexus* to light vary somewhat with age; newly emerged individuals avoid strong light, whereas the older ones are more light-tolerant. Sex difference is a possible source of variation in the laboratory tests. It was not possible to determine the sex of the living adults, and the experimental groups probably contained both males and females, in unknown ratios. In addition to the foregoing, differences in the life-histories and habits of the species should be considered in interpreting the laboratory results. *C. nigrocellulata* and *N. obscura* have more than one generation each year and the adults do not overwinter and are not predatory. Adults of these species have shorter life spans than those of *A. obliterata*, *L. erichsonii*, and *P. impexus*. The last-named species have one generation yearly and the adults overwinter in an inactive state and are predatory.

Obervations on larvae of *A. obliterata*, *C. nigrocellulata*, *L. erichsonii*, and *P. impexus* indicated that locomotion is not greatly influenced by light intensity or temperature. Though the method used was not sufficiently refined to determine the stimuli that elicit movement and feeding, it made possible a general comparison of the motilities of the last-instar larvae at high prey density. The sequence of species in descending order of locomotory activity of last-instar larvae on the basis of field observations at high prey density is: *P. impexus*, *A. obliterata*, *L. erichsonii*, and *C. nigrocellulata*.

The laboratory tests on the responses of adults to light confirmed the field observations for *N. obscura* and provided a better understanding of the light relations of the other species. *A. obliterata* is attracted to direct light, whereas *P. impexus*, though not attracted to direct light, is attracted to indirect low-intensity light. *L. erichsonii* is not strongly attracted to indirect light. Present evidence indicates that in descending order of tolerance of adults to light the arrangement of species is: *N. obscura*, *A. obliterata*, *P. impexus*, and *L. erichsonii*.

In view of differences in responses to light and in feeding habits of adults of *C. nigrocellulata*, *L. erichsonii*, *N. obscura*, and *P. impexus*, exposure to highly contrasting light intensities might be expected to produce different effects on their locomotory patterns. However, pronounced differences were not observed. The greater frequency of path-crossing at low light intensity than at high indicates that more new area is covered by all species at high light intensity.

The walking rate of the crawler of *A. piceae* is high for the size of the insect. This rate increases with increases in light intensity and temperature. The increases at the higher light intensities in part probably reflect attempts by the crawler to avoid the light. Balch (1952) showed that the crawler is

attracted to diffuse light of moderate intensity, but avoids strong direct sunlight.

Summary

In field tests the feeding last-instar larvae of *Aphidecta obliterata* (L.) and *Pullus impexus* (Muls.) covered greater areas of bark than those of *Cremifania nigrocellulata* Cz. and *Laricobius erichsonii* Rosenh., and the locomotory activities of the species were not greatly affected by changes in air temperature. Adults of *C. nigrocellulata* and *Neoleucopis obscura* (Hal.) made short flights to areas of sunlight at 15° to 25°C., whereas adults of *A. obliterata*, *L. erichsonii*, and *P. impexus* did not often fly but were stationary or walked on the bark surface. These species walked at temperatures ranging from 8° to 25°C. The probable sequence of the species in descending order of tolerance of adults to light on the basis of field observations and laboratory tests is *N. obscura*, *C. nigrocellulata*, *A. obliterata*, *P. impexus*, and *L. erichsonii*. In laboratory tests, adults, except of *A. obliterata*, were active from approximately 3° to 22°C., the frequency of stopping was greater for all species except *N. obscura* at high light intensity than at low, and the frequency of path-crossing was greater for the four species at low light intensity than at high. The walking rate of the crawler of *A. piceae* in the laboratory was greater at high light intensity than at low, and at the higher test temperatures.

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Movement of Food in the Gut of Some Adult Stored Grain Beetles

By R. N. SINHA[1,2]
Department of Zoology, McGill University
Montreal 2, Canada

Introduction

The time required for passage of food through various segments of the alimentary canal is important in understanding the process of digestion in insects. Abbott (1926) gave some information on this subject in connection with his study of the physiology of digestion in the Australian roach, *Periplaneta australasiae* Fab. Snipes and Tauber (1937), have recorded the time required for passage and ejection of one type of food in the American cockroach, *P. americana* L. Later Day and Powning (1949) studied the time taken for starch paste to reach different parts of the alimentary canal of the German cockroach, *Blattella germanica* (L.). But any information in this respect seems to be lacking in numerous species of insects other than the cockroach. This study was undertaken to determine the time required to reach various points of the gut of small stored grain beetles, to find out the difference in the time requirement between two closely related species living on same diet and between large and small insects. Investigations were also made to locate the region of mixing in the gut of two subsequent meals, to understand the significance of certain anatomical structures in the gut in relation to the movement of food. The adult beetles used in these experiments were, *Tribolium confusum* Duv., *T. castaneum* Herbst (Fam. Tenebrionidae), *Oryzaephilus surinamensis* (L.), *O. mercator* (Fauval) and *Laemophloeus pusilloides* Steel and Howe (Fam. Cucujidae).

Materials and Methods

Fully grown adult beetle (age 2 weeks or more in *Tribolium*; 1 week or more in *Oryzaephilus*), taken from the inbred cultures maintained for three years at 30°C. and 70 per cent R.H. in the laboratory of Prof. J. Stanley, in the Department of Zoology, McGill University, were used in this study. Out of approximately 200 insects used, 168 were dissected (*T. confusum*–76, *T. castaneum*–37, *O. surinamensis*–27, *O. mercator*–20, and *L. pusilloides*–8), and the rest were used for the study of hunger and feeding habits. Adults of *Laemophloeus pusilloides* were received from the culture maintained in the Stored Grain Insect Laboratory, Canada Department of Agriculture, Ottawa. Individuals of *Oryzaephilus*, *Laemophloeus* and *Tribolium* were deprived of food for 2, 1 and 5 days respectively, after which they were fed with a mixture of wheat flour (60 mesh particles) and a vital dye for various lengths of time. The feeding was followed by a heat shock from a 100 watt electric lamp which killed the insects instantly without causing detectable change in the structure of the gut from those killed by chloroform or ether vapour. Of the three supra vital dyes used, orange G, carmine and trypan blue, trypan blue was found to be the most suitable. Every insect was dissected immediately after death with fine needles (needles made from blown out glass rods were used for *Laemophloeus* and often *Oryzaephilus*) under a stereo microscope at 60x to 160x magnification. The presence of the coloured food at a certain point of the alimentary canal was usually observed from outside the semi-transparent wall of the gut. The contents inside any particular region of the gut were taken out and carefully examined in doubtful cases. Transmitted

1Post-doctorate Fellow, National Research Council of Canada.
2Present address: Science Service Laboratory, Canada Dept. of Agriculture, Box 322, University of Manitoba, Winnipeg, Manitoba.

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light was used to study the movement of the mouth parts and the different parts of the alimentary canal.

In Figs. 1-3 only the minimum time required for food passage to various points of the alimentary canal has been shown.

In Table I, all measurements of the gut were taken from dead specimens and whole mounts.

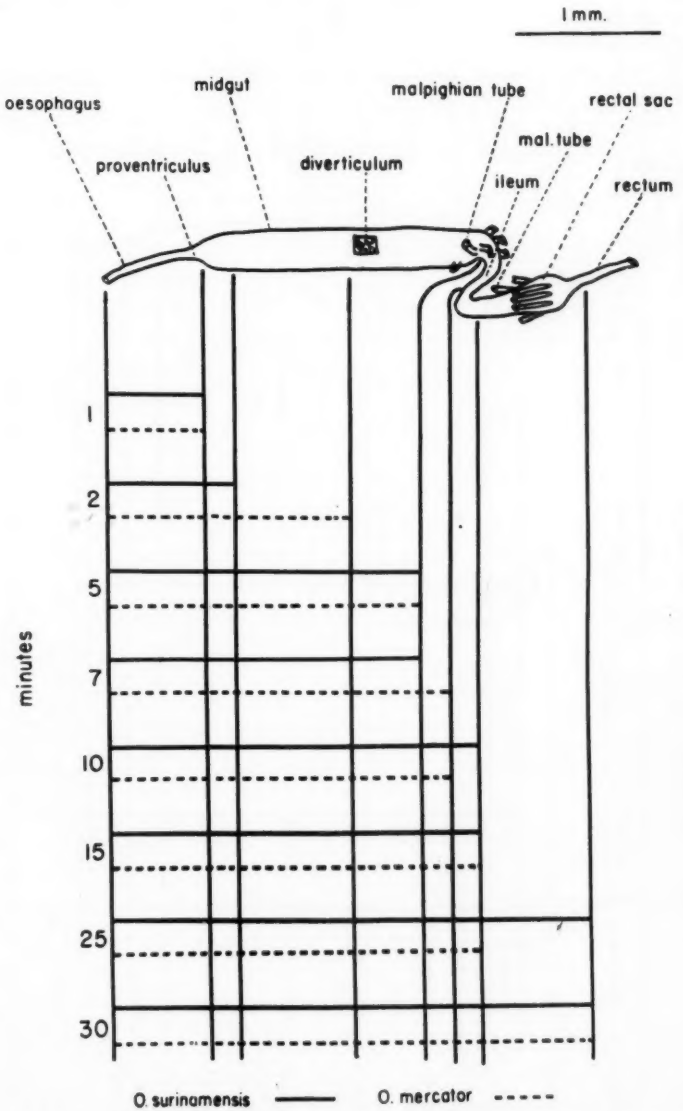

Fig. 1. Diagram showing the passage of food through the alimentary canal of two species of *Oryzaephilus*.

TABLE I

Approximate Dimensions, Time Required for Food Passage and Rate of Movement of Food Through the Gut of Various Species of Cockroaches and Stored Grain Beetles

Species	Author	Length (mm.)	Max. Width	Length of gut (mm.)			Ratio, body	Time (minutes) Distance	
				Foregut	Midgut	Hindgut	gut length	Mouth to Ileum	Mouth to Rectum
Blatella germanica	Day and Powning 1949	11	5	7	10	10	2 5:1	90	120
Periplaneta americana	Snipes and Tauber, 1937	40	13	18	18	25	1.5:1	180	480
Periplaneta australasiae	Abbott, 1926							300	420
Laemophloeus pusilloides	Sinha	1.8	0.4	0.3	1.3	1.2	1.5:1	25	35
Oryzaephilus mercator	Sinha	3	0.6	0.5	1.8	1.8	1.4:1	7	30
Oryzaephilus surinamensis	Sinha	3	0.6	0.7	1.8	1.6	1.4:1	10	25
Tribolium confusum	Sinha	4.5	1.1	0.6	2.7	3.2	1.4:1	45	60
Tribolium castaneum	Sinha	4.5	1	0.8	2.7	2.7	1.3:1	60	80

The drawings of the alimentary canals were made through bioscope and the necessary reduction and enlargement were done by a pantograph.

Hunger and Feeding

Some observations on the mechanism of hunger and feeding were made with the adult *T. confusum*. *T. confusum* appears to be a continuous feeder. The insect often remains motionless and feeds with irregular movement of the mouth

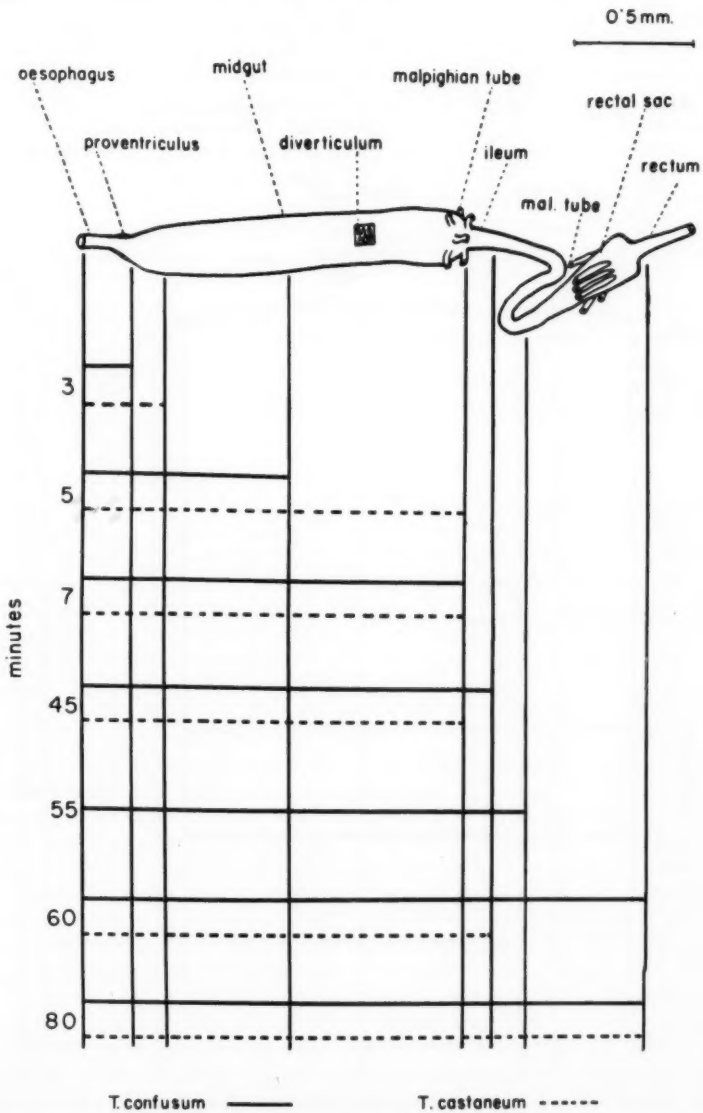

Fig. 2. Diagram showing the passage of food through the alimentary canal of two species of *Tribolium*.

parts. It does not show any superficial sign of movement except occasional shifting of position of the middle legs. The insect responds to changing external stimuli such as touch or light and moves frequently without stopping to eat. Normally it grasps particles of flour with the maxillary palpi and passes them on to the oral cavity through mandibles which show continuous horizontal movement. Mandibles usually alternate lateral motion with the maxillary palpi opening and closing the oral cavity in quick succession. Lumps of food particles are

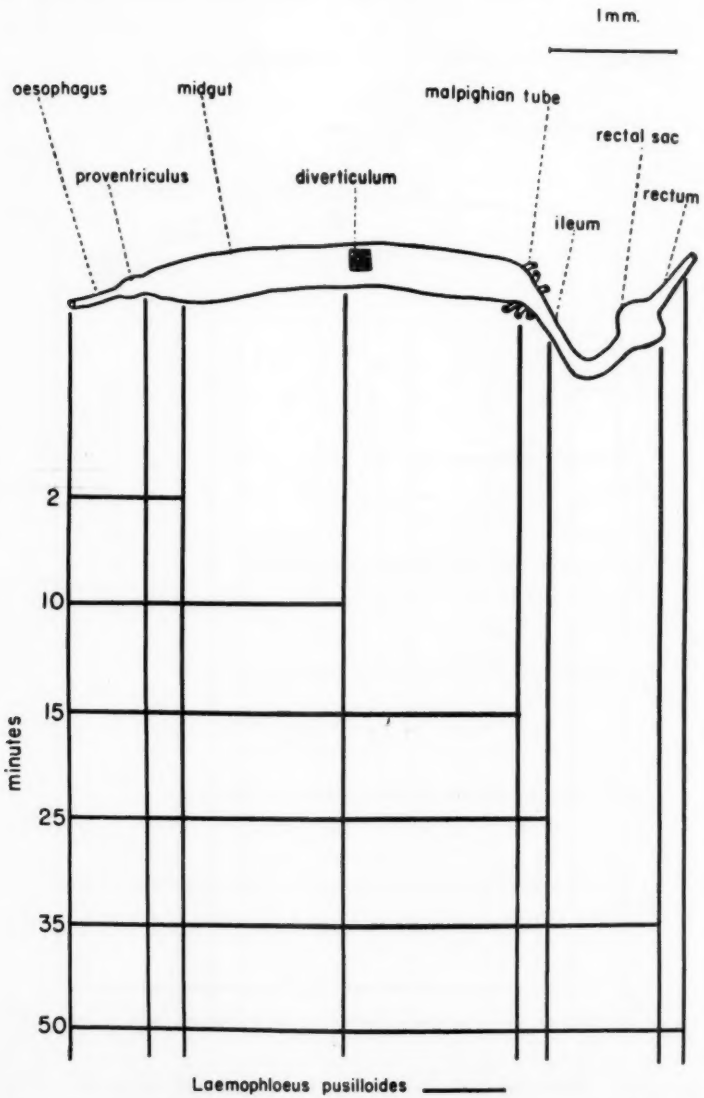

Fig. 3. Diagram illustrating the passage of food through the alimentary canal of *Laemophloeus*.

thrashed by the pressure of the dark molar area at the base of each mandible. The grinding of food can be easily seen through the dark cuticle of the head with transmitted light. No characteristic orientation of the head and body is noticed in unstarved insects. On the other hand, an insect starved for five days reacts to food by gradually bending the body in the shape of a bow, at the junction of the thorax and abdomen. This is done by straightening the middle legs at the joints between tibiae and basitarsi. The tarsal segments in a well-fed insect usually remain flattened against the walking surface thereby making almost a right angle with the tibiae. The junction between the head and thorax does not bend much while feeding. In the feeding position, the insect usually rests its body on the distal ends of the tibiae of the first pair of legs. Besides, as the first reaction to food, a hungry insect passes through a period of excitement manifested by fast and irregular movement. Eventually, it comes across the food and stops almost instantly and starts to eat, remaining in this characteristic position. Some of them have been observed to remain for an hour or more at one spot. They seem to be absolutely motionless when seen without magnification. But continuous movement of the maxilla, mandible and to a lesser degree the first pair of legs are easily noticeable on close observation through a stereo microscope with transmitted light.

When a speck of food was placed at the centre of a Petri dish (4″ diameter) and the hungry insects were released near the edge, the greatly excited insects moved irregularly and appeared to reach the food at the centre simply by chance. Even after the first encounter with food, an insect wandered repeatedly in and out of the area of food, grasping some food particles while in motion. Finally, it started feeding quietly.

Food Transport

Propulsive movement of some parts of the alimentary canal has been observed in freshly killed *T. confusum* and *T. castaneum.* Peristaltic movement of the ileum and the rectal sac is noticeable for several minutes after the insect has been dissected open. Indirect evidences of antiperistaltic movement have been found in the proventriculus near the junction of the fore-gut and the midgut. Insects fed with a mixture of wheat flour and a p H indicator such as Bromo-cresol green, Bromo-cresol purple, Bromo-phenol red and Bromo-thymol blue have always recorded the p H specific for the midgut in the proventriculus a few hours after the feeding instead of the pH characteristic of the proventriculus which is usually recorded before food can reach the midgut. There can be two possible explanations for two different pH records of the proventriculus. First, the pH of the proventriculus is variable at various phases of digestion. Secondly, a partial digestion actually takes place in the posterior half of the proventriculus behind the circular row of strong hairs (Sinha, 1958; Sinha, in preparation), necessitating the food to move towards the foregut from the midgut by antiperistaltic movement. Dennell (1942) has observed in the granary weevil, *Calandra* that the proventriculus serves to withhold small particles of food in the crop while allowing the digestive juice from the midgut to pass forwards. But the posterior part of the proventriculus of *Tribolium* has been found to be packed with lumps of food even after 14 days of starvation. The foregut up to the anterior part of the proventriculus has always been found empty after five days of starvation in at least 50 insects dissected. Moreover, the posterior part of the proventriculus has also been observed to be almost empty, or only partially filled with particles of food, one day after the second period of starvation is begun. These observations strongly suggest that there has been a transfer not only of digestive fluids but also of the food from the midgut by some mechanical means.

Time Required for Passage of Food Through Different Parts of the Gut

The main difficulty in determining the time required for food to reach different regions of the alimentary canal arises from the irregularities of the duration of food in any region of the gut from individual to individual. Since the factors which are responsible for such delays are often unknown, it is hardly meaningful to give a statistical analysis of the data. Therefore, only the minimum time required for the passage of food through different parts of the alimentary tract has been presented in Figs. 1-3. Although the previous workers (Day and Powning, 1949; Snipes and Tauber, 1937) have not mentioned this, it seems that they have used the minimum time in their work with different species of the cockroach.

In Figs. 1 and 2, a comparison of the rate of passage of food between two closely related species of *Oryzaephilus* and *Tribolium* has been made. Horizontal lines indicate the position of food in the gut reached after various intervals of time. The solid and broken lines represent the two species of the genus. Contrary to what has been observed in the cockroach (Abbott, 1926; Day and Powning, 1949), food is not held in the proventriculus at the junction of foregut and midgut for any appreciable length of time in *Oryzaephilus* and *Tribolium*. In both groups food reaches the midgut within a minute after its arrival at the proventriculus. But in *Laemophloeus* (Table III), food is probably detained for a short period, between 2 to 10 minutes, in the proventriculus before it moves into the midgut. The second effective barrier is at the junction of the midgut and hindgut where the Malpighian tubes open into the gut. Food is held at this point for 7 to 10 minutes in *Oryzaephilus* (Fig. 1), 45 minutes or less in *Tribolium* (Fig. 2) and 15-25 minutes in *Laemophaelus* (Fig. 3). These time intervals are considerably less than those found in cockroaches, *Periplaneta australasiae* (Abbott, 1926) and *Blattella germanica* (Day and Powning, 1949).

Food moves fast through the narrow tubular ileum until the rectal sac is completely filled in all the species studied. Once the rectal sac is filled with food the ileum becomes gradually blocked by food from posterior towards the anterior part of the tract. Finally, in an insect well-fed after prolonged starvation, food forms a continuous thread-like mass from the posterior part of midgut to the rectal sac. When dissected out, this solid mass of food can be unwound into a long thread which, in natural position, is accommodated in a zig-zag fashion within the rectal sac of *Tribolium*.

After the ileum of the hindgut has been reached, the rate movement of the food becomes extremely variable depending upon the availability of space in the rectal sac. This is variable in various species studied.

In *Tribolium*, the rectal sac rarely empties completely even after two weeks of starvation yielding an unhampered passage for the backward moving food through the entire rectum. Some insects have been observed to retain excreta in the rectal sac until death due to starvation. For this reason, the ejection time of the faecal pellets of *Tribolium* cannot be determined with reasonable significance. Similar observations have also been made in case of *Oryzaephilus*. But in *Oryzaephilus* insects with almost empty rectum can be obtained if they are allowed to starve for five to seven days, often at the cost of heavy mortality. Since vigorous adults of *Oryzaephilus* starved for two days have been used for these experiments, the exact time of the arrival of food in the rectum proper could not be determined. A variable quantity of food has always been retained in the posterior part of the rectal sac, causing hindrance to the free passage of the coloured food used for the study. The rectal sac of *Laemophloeus* starved

for a day was almost empty and the time to reach a certain distance before the anal opening could be determined. (Fig. 3).

The time required to reach the rectal sac or the region of absorption of water is 25 minutes in *Oryzaephilus surinamensis* and 30 minutes in *O. mercator* (Fig. 1). Food reaches the end of rectal sac 20 minutes earlier in *Tribolium confusum* than in *T. castaneum* which arrives at the same point of the gut in 80 minutes (Fig. 2). In *Laemophloeus* the end of the rectal sac is reached in 35 minutes, and the rectum proper in 50 minutes.

In order to determine whether there is any correlation between the movement of food and the actual distance travelled, various measurements of the body and the alimentary canal of different insects have been presented along with the minimum time required for food to reach two important points of the gut (Table I). The available information about three other species studied by previous workers has been incorporated to the table for comparison. The rate of movement of food per minute can be roughly calculated from Table I, disregarding the fact that food remains for variable periods in certain regions of the alimentary canal. According to such an arbitrary comparison, *B. germanica* shows the fastest movement. The other species come in the following order, *O. surinamensis, O. mercator, P. americana, T. confusum, L. pusilloides and T. castaneum.* But a comparison of this sort is not likely to have much value in determining the natural rate of movement, if any such thing at all exists.

Of the common barriers affecting the uniform movement of food in the stored grain beetles studied, the pyloric region is most important. As in cockroaches studied by previous workers (Day and Powning, 1929; Snipes and Tauber, 1937; Abbott, 1926) food is held for a considerable amount of time in the midgut of the stored grain beetles before it is gradually released in the ileum.

Food is held at the junction of foregut and midgut for nearly 30 minutes in *P. australasiae* (Abbott, 1926), 7 minutes in *B. germanica* (Day and Powning, 1949); this permits the digestion of fat in the crop before it enters the midgut.

Unless the midgut is filled with food or an air bubble, food is never found to be detained at the junction of the foregut and midgut of any of the stored grain beetles studied.

The barrier encountered in the rectal sac and the rectum for the uniform movement of the food is purely due to the blocking of the space by previously accumulated faecal matter.

Mixing of Meals

In order to find out the areas of mixing of two successive meals starved individuals of *Tribolium confusum* were allowed to feed for 20 minutes on flour mixed with orange G, they were subsequently transferred to a meal of flour mixed with trypan blue and were examined 1 hour and 20 minutes later. It was found out that some mixing took place in the proventriculus whereas most of the mixing occurred in the posterior part of the midgut and anterior part of the ileum. This observation corresponds with those of Day and Powning (1949) in the cockroach.

Retention of food by the proventriculus

Tribolium confusum and *T. castaneum* can retain food in the proventriculus for a long time. Several insects of these species were starved for 5 days, fed for two hours and finally starved for several weeks until all the individuals died. Even after two weeks it was observed that the posterior part of the proventriculus just behind the row of hairs was still filled with food. Of course, in some individuals the proventriculus was found to be almost empty after 1-2 days. As mentioned before, it is possible that food has been regurgitated from the midgut

to the proventriculus in course of the slow process of digestion. The food recovered after two weeks from the proventriculus was always behind the row of strong hairs (Sinha, 1958 in press), in the shape of a cone with the flat base projecting forwards.

O. surinamensis and *O. mercator* were starved for two days, fed for 6 hours, and finally starved for several days until all the individuals died. In both species the proventriculus was found empty after one day. It is interesting to note that Abbott (1926) has observed that the proventriculus of *P. australasiae* is usually found to be empty after about one week of starvation, whereas Day and Powning (1949) state that at least three days are required to empty the proventriculus of *B. germanica* after a full meal.

Retention of Food by the Midgut

Food is retained in the midgut, probably at different phases of slow digestion and in variable quantities, for a considerable length of time, often until death. Most individuals of *O. surinamensis* and *O. mercator* die within a week of starvation preceded by a full meal. But in all the surviving individuals, the midgut showed some traces of food. The same statement can be applied to *T. confusum* and *T. castaneum* in which death due to starvation does not usually start until two weeks of starvation after a full feeding. Day and Powning (1949) found only some dye in granules in the midgut and hindgut of *Blattella* after 4 days and considered the insect to be starved when it was removed from all food for three days. But in several individuals of *Tribolium* and *Oryzaephilus* the midgut was observed to be partially or almost completely filled with food after two and one week respectively. Therefore, unlike the cockroach, stored grain beetles take a longer time to be completely starved.

Retention of Food in the Hindgut

The ileum rarely retains food. Movement of food through the ileum appears to be faster than any other part of the gut except probably the oesophagus. When the rectal sac is full, a continuous thread-like mass of food has often been observed in the ileum.

In most of the stored grain beetles, especially in *Tribolium*, food is retained for an unlimited period of time in the rectal sac until it is ejected by mechanical pressure exerted from the anterior part of the gut through continuous feeding. *Tribolium* has often been found to retain a large amount of dry faecal matter 24 days after being removed from food. An almost empty rectal sac has been observed in *Laemophloeus* after a day of starvation. The rectal sac was found to be full of food at the end of 6 days of starvation in *Oryzaephilus*.

The rectum proper has been found to be empty in most dissections of stored grain beetles. Perhaps the process of ejecting faecal pellets is extremely fast when it occurs.

Movement of Food and Structure of Gut

Sinha (1958a; 1958b) has recently described the structural details of the gut of the adult *T. confusum*, *T. castaneum*, *O. surinamensis* and *O. mercator*. The present study of the movement of food through the gut seems to have revealed the functional significance of some of those anatomical characteristics.

The anterior part of the proventriculus possesses strong and posteriorly directed hairs in *Tribolium*. One function of these hairs is probably to stop the backward movement of the food regurgitated from the midgut in course of the prolonged period of digestion. The function of the strongly developed proventricular valve is more to aid the reverse movement of the food from the midgut to the posterior half of the proventriculus than to facilitate the rearward

movement or the control of the flow of food like a sphincter as was previously supposed (Sinha, 1958a).

The well-developed pyloric valve at the junction of the midgut and hindgut almost certainly controls the flow of the food material into the ileum.

A large number of rows of comb-like hairs have been described in the inner wall of the ileum of *T. confusum*, *T. castaneum*, *O. surinamensis* and *O. mercator*. These row of hairs, accompanied by strong circular muscles, may be responsible for the extremely fast movement of food through the ileum.

The zig-zag longitudinal muscles along the wall of the rectal sac may simply facilitate the prolonged and continued storage of faecal matter and exert little pressure by contraction in ejecting the excreta. There is a layer several strands thick circular muscles in the wall of the rectum proper contrasting with the absence of similar muscles in the wall of the rectal sac. The probable function of these muscles is to eject the faecal pellets as soon as they reach the rectum proper from the region of storage in the rectal sac.

Summary

1. Various aspects of the movement of food in the alimentary canal of the stored grain beetles, *Oryzaephilus surinamensis*, *O. mercator*, *Tribolium confusum*, *T. castaneum* and *Laemophloeus pusilloides* reared at 30C and 70% R.H. have been studied.
2. The hunger and feeding behavior of *T. confusum* have been described.
3. Marked peristaltic movement of the ileum and the rectal sac has been noticed. Evidences of antiperistaltic movement has been found in the region of the junction of the foregut and midgut.
4. In an insect starved for 1-5 days, the minimum times required for food to reach the junction of foregut and midgut, the junction of the midgut and hindgut, and the end of the rectal sac, are 1, 5, 25 min. in *O. surinamensis*; 1, 5, 30 min. in *O. mercator;* 3, 7, 60 minutes in *T. confusum;* less than 3, 5, 80 min. in *T. castaneum*; and less than 2, 15 and 35 minutes in *L. pusilloides*.
5. After a full meal for 2-6 hours, the proventriculus and midgut do not empty completely even after starvation of 1 week in *Oryzaephilus* and 2 weeks in *Tribolium*.
6. In *T. confusum*, the mixing of two successive meals with an interval of 20 minutes takes place in the proventriculus, the posterior part of the midgut and the anterior part of the ileum.
7. During starvation after a full meal of a few hours, the food remains in the rectal sac for 1 week in *Oryzaephilus* and 3 weeks to the time of death in *Tribolium*.
8. The correlation between the movement of food and the structural modification of the gut of *T. confusum*, *T. castaneum*, *O. surinamensis*, and *O. mercator* has been discussed.

Acknowledgments

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Techniques for Biological Studies of Tetranychid Mites, Especially *Bryobia arborea* M. & A. and *B. praetiosa* Koch (Acarina: Tetranychidae)[1]

By C. V. G. Morgan[2] and N. H. Anderson[3]
Entomology Laboratory, Summerland, B.C.

Biological studies of tetranychid mites have been hampered by lack of suitable techniques for studying and handling the mites in the field and laboratory. Common entomological methods are not readily adaptable for studying these minute animals. During population studies of orchard mites in British Columbia, the authors devised some field and laboratory techniques for studying the life-histories of the brown mite, *Bryobia arborea* Morgan and Anderson, the clover mite, *B. praetiosa* Koch, and the European red mite, *Metatetranychus ulmi* (Koch).

Trapping the Clover Mite

The clover mite feeds on herbaceous plants and seeks dry, protected sites, such as in cracks in fence posts, beneath bark scales on tree trunks, and under sheathing of buildings, in which to oviposit, moult, and hibernate. It is difficult to make observations in and collect samples from such situations. Moreover, as the mites frequent the same sites year after year, the cast skins and dead eggs that accumulate hinder accurate work. To overcome these handicaps a trap was designed that appears to be as acceptable to the mites as a natural hibernaculum. This provides protection under dry, dark conditions, contains grooves simulating cracks and fissures in bark or wood, is built in sections so that specimens may be removed without disturbing the remainder of the colony, may be placed in any convenient site where mites are present, and is inexpensive and easily constructed.

The trap (Fig. 1) consists of a centre stake to which quarter-inch plywood boards are attached. The stake is about 18 inches long, four inches wide, and two inches thick, and has a carriage bolt inserted from each side, near the centre. Shallow groves are cut on one side of each plywood board, and a hole is bored in the centre of the board. Four boards, each about 12 inches square, are placed on each bolt, with the vertical grooves on the inner surface, and held in position

1Contribution No. 3626, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.
2Associate Entomologist, Entomology Laboratory, Summerland, B.C.
3Assistant Entomologist; now at Entomology Laboratory, Belleville, Ontario.

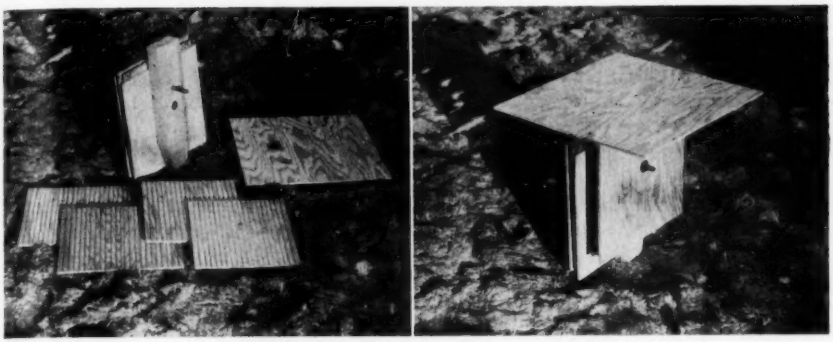

Fig. 1. Plywood trap used for studying the clover mite, *Bryobia praetiosa*. Left, with one side and top removed. Right, assembled for use.

by a wing nut. By unscrewing the nut, one or more of the boards may be removed and replaced without disturbing the remainder. A 15-inch square of plywood is nailed to the top of the stake to keep the trap dry. The stake is driven into the soil until the lower edges of the boards are within a few inches of the ground. The mites enter the trap by crawling up the stake and then between the boards. A smaller trap would probably be equally useful and less cumbersome.

The trap also serves as a site for the deposition of winter eggs of the brown wheat mite, *Petrobia latens* (Müller), and is probably suitable for studies of that mite and of others with similar habits.

Recording Emergence of Larvae

Both the European red mite and the brown mite overwinter in the egg stage on the lower surfaces of fruit spurs and twigs. It is difficult to determine the period and rate of hatching of eggs in such sites. A convenient technique was devised for studying these eggs under field, insectary, and laboratory conditions without removing them from the twigs. A piece of twig about one inch long, and bearing eggs, is stapled to an index card. A barrier of Deadline (California Spray Chemical Corp., Portland, Oregon) is spread around the edge of the card to trap the larvae. On hatching, the larvae crawl away from the twig and are caught in the barrier. As they are bright red in color, they are easily seen against the white background of the card, and may be removed with a dissecting needle while they crawl over the card or after they are trapped in the colorless Deadline. These cards may be attached to the lower surfaces of tree limbs or used in artificial environments such as insectaries or constant temperature cabinets.

Deadline spreads in hot weather and, if applied too thickly, the oily film may eventually come in contact with the bark of the attached portion of twig and affect the development of the eggs. Also, this barrier collects dust and small insects. If too much debris accumulates some mites may escape over the barrier and those that are trapped are difficult to see. To avoid such difficulties, the Deadline should be scraped off and replaced when necessary. Deadline is particularly useful under field conditions because it is not appreciably affected by rain.

A similar type of card was used for studying clover mite eggs. Bark scales bearing eggs are too brittle to be readily stapled to the cards, but small sections

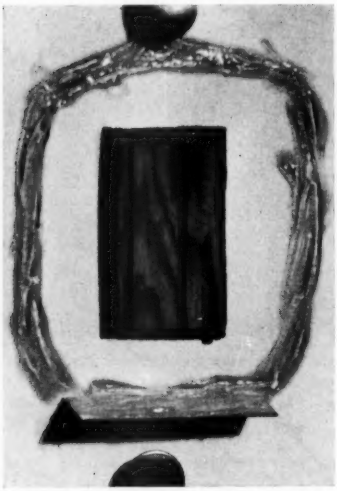

Fig. 2. Larval emergence card used for the clover mite, *Bryobia praetiosa*.

of wood cut from the plywood trap described above are satisfactory. The cards are suitable when placed on a horizontal surface, but require a modification if attached to a vertical support such as a tree trunk or a post. In contrast with the European red mite or the brown mite, larvae of the clover mite are positively geotropic and after hatching drop or crawl to the cover crop. On vertical cards a small cardboard shelf coated with Deadline is attached below the plywood section to trap the larvae (Fig. 2). The shelf is particularly useful when large numbers of larvae are hatching, as it is easily removed and replaced. The larvae on the original shelf may be counted when time permits.

Sampling Clover Mite Populations

It has not been possible to develop an accurate sampling technique for estimating numbers of the clover mite during the summer. The numbers on the host plants continually fluctuate because of movement to and from the moulting and oviposition sites. In addition, the activity of the mites is influenced by weather. Leaves cannot be used as the sample unit because the mites immediately drop from the plant when it is disturbed.

Qualitative samples of active stages may be obtained by sharply tapping the host plants over a shallow box. The box is emptied into a mite brushing machine that distributes the mites uniformly over an adhesive-coated, revolving plate (Morgan *et al.*, 1955). The mites on the plate are then counted under a stereoscopic microscope. Samples obtained by beating herbaceous plants do not include eggs and quiescent stages. These immotile stages may be counted at intervals in a specific section of the plywood trap. The sizes of samples from beating and from the trap are not necessarily equal, but the combined results serve to indicate population trends.

A quantitative estimate of the mite population may be obtained during the late fall and winter, when the mites are relatively inactive. Mortality, rate of winter egg deposition, and percentage of each stage overwintering may be determined by counting the mites in the same section of a trap at each sampling date.

Laboratory Rearing

A modification of the leaf-disk technique as used by Siegler (1947) for testing acaricides proved a convenient method for rearing mites individually in the laboratory. A detached leaf is placed on a pad of moistened absorbent cotton in a 10-cm. petri dish. The petiole is removed and the leaf pressed against the wet cotton. When in contact with the cotton, the leaf remains flat, preventing the mite from crawling to the underside. The cotton is kept sufficiently moist to provide a thin film of water around the edge of the leaf. This film forms a barrier through which few of the mites will move.

The cotton pad method has several advantages over the floating, detached leaf method of Rodriguez (1953). The dish does not require watering so frequently. Fewer mites are lost by drowning because there is less tendency for the water to flow over the edge of the leaf if the dish is moved. A floating leaf is difficult to examine microscopically because it moves about too freely. If one applies too much pressure to a floating leaf while handling mites with a dissecting needle, the meniscus is broken and the leaf partially flooded.

The cotton pad method is ideally suited for rearing summer generations of the European red mite and mites of the genera *Tetranychus* and *Eotetranychus*.

Acknowledgments

The authors were assisted in this work by Mr. Harry Dominique, formerly of the Biological Control Section, Entomology Laboratory, Vancouver, B.C. The plywood traps were constructed by Mr. G. F. Lewis, Entomology Laboratory, Summerland, B.C. Mr. S. R. Cannings, Canada Experimental Farms Service, Summerland, B.C., photographed the equipment.

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The Larvae of *Deilinea* Hübner (Lepidoptera: Geometridae), with Notes on Other Stages[1]

By W. C. McGuffin
Forest Zoology Laboratory, Calgary, Alta.

The major concern of this work is a study of the external morphology of larvae of the Canadian species of *Deilinea* Hübner: *D. borealis* Hulst, *D. erythemaria* Guenée, *D. exanthemata bryantaria* Taylor, and *D. variolaria* Guenée. Observations on the life history and habits of two of these have been included.

The field work was carried out in 1955 and 1956 at the Kananaskis Forest Experiment Station, Seebe, Alberta. This station is on the east slope of the Rocky Mountains (Latitude 51°) and the observations were made at an altitude of about 4,500 feet.

Larva

External morphology

The slender larvae of *Deilinea* have rounded heads (Fig. 7). The cuticle appears smooth at low magnifications. The labrum is about three times as long as wide at the notch (Fig. 6). It varies in shape from instar to instar but does not differ greatly from species to species. The mandibles have nine or ten teeth. There is little interspecific variation but the sharp-toothed first instar mandible differs from the blunt-toothed ones of the other instars (Figs. 12 and 13). The antennae and maxillae show little variation in these species. The hypopharynx is smooth and bears the conical spinneret at its tip. The spinneret is about twice as long as wide (Fig. 14). The labial palpus is two-segmented. There are six ocelli arranged in a semi-circle on each side of the head.

The cuticle of the thorax and abdomen appears smooth at low magnifications and granular or tomentose at high (Figs. 2 and 3). Each thoracic leg is tipped with an acutely angled claw (Fig. 11). The prolegs have the crochets arranged in a biordinal, interrupted mesoseries (Fig. 10). There are five setae on the side of each ventral proleg. The anal plate is similar in all species (Fig. 5). The hypoproct and paraprocts are poorly developed.

The Hinton (1946) system of setal classification has been applied to these larvae, with three exceptions: the "frons" is here considered to be a continuation of the clypeus, the "adfrontals" are the frons, and there is an extra L seta (L-4) on abdominal segments two to five inclusive. The setal arrangement on the head of a mature larva is illustrated in Fig. 7. The setal patterns of the thorax and abdomen are shown in Figures 15 to 20.

Colour pattern and size

First Instar: The head is pale orange in *D. erythemaria* (Dyar, 1903) and pale brown or honey-coloured in the other species. There is a brown bar on the lower part of the parietal lobe. The thorax and abdomen of all species are pale yellow or pale yellow-green, with brown or reddish-brown middorsal and subspiracular lines.

The width of the head varies from 0.25 to 0.28 mm. in *D. variolaria*, from 0.29 to 0.31 mm. in *D. erythemaria* and from 0.30 to 0.34 mm. in *D. borealis* and *D. exanthemata bryantaria*. The length of the body varies from 1.5 to 4.0 mm. and the width from 0.17 to 0.40 mm. (The length is roughly 10 times the width). There are 6 or 7 crochets on the ventral proleg.

[1]Contribution No. 396, Division of Forest Biology, Science Service, Department of Agriculture, Ottawa, Canada.

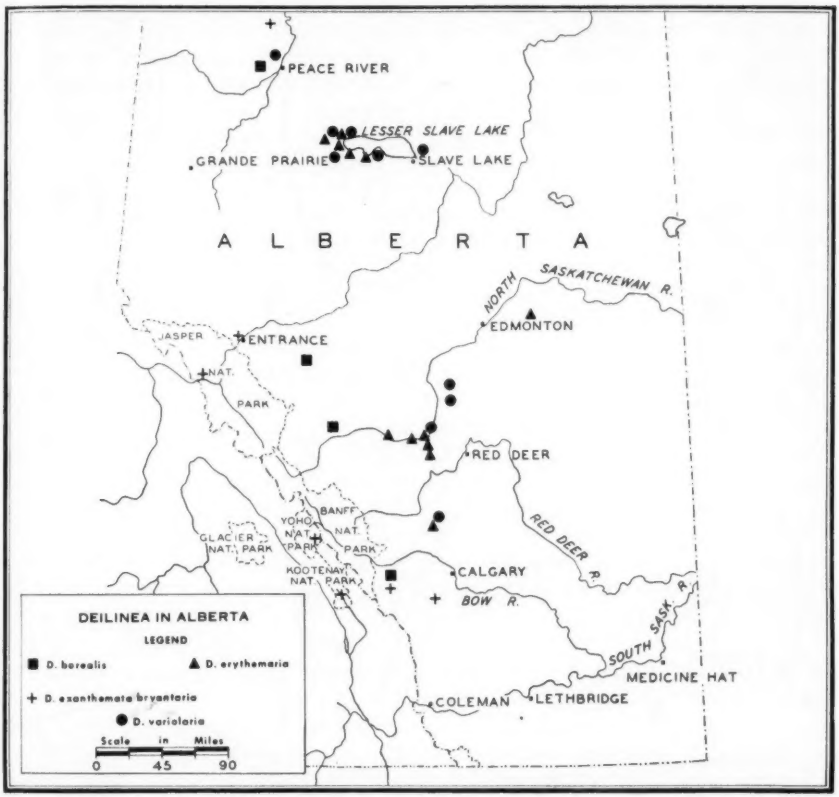


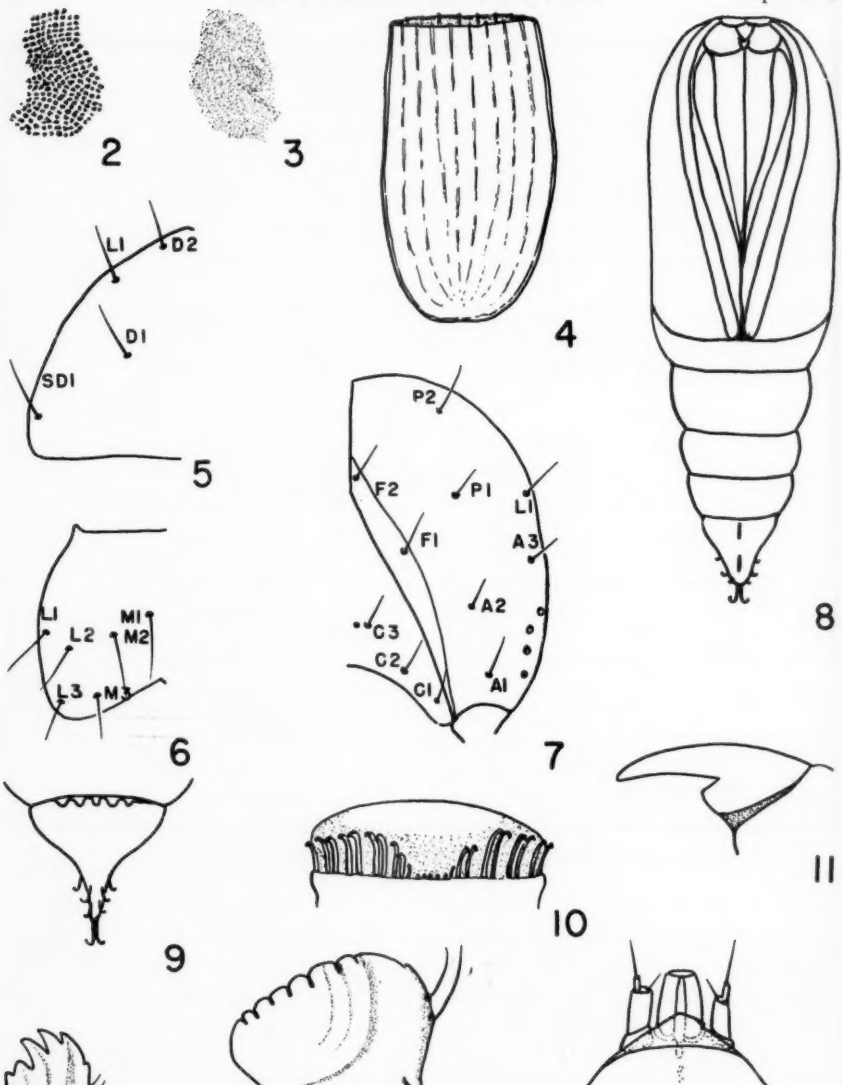
Fig. 1. Distribution map of *Deilinea* in Alberta as shown by Forest Insect Survey records.

Second Instar: The pattern of all four species is similar. The head is pale brown or russet-brown, with a brown or black line on each parietal lobe and a dusky band along the epicranial stem. The thorax and abdomen are pale green with wide brown middorsal and subspiracular lines.

The head width of *D. variolaria* is 0.45 to 0.50 mm., of *D. borealis*, 0.48 to 0.56 mm., and of *D. erythemaria* and *D. exanthemata bryantaria*, 0.50 to 0.56 mm. The length of the body varies from 3.4 mm. in *D. erythemaria* to 8.0 mm. in *D. exanthemata bryantaria*. The width of the body is 0.4 to 0.5 mm. There are from 8 to 10 crochets on each ventral proleg.

Third Instar: The head is patterned much the same as in the second instar but the dusky median line may not always be present. The thorax and abdomen are pale green. In all species there is a broad, brown subspiracular line. There is a broad, brown middorsal line in *D. borealis*, *D. erythemaria* and *D. variolaria* and a fine brown or grey line in *D. exanthemata bryantaria*.

The head width varies from 0.65 mm. in *D. variolaria* to 1.00 mm. in *D. erythemaria*. The length of the body varies from 7 to 10 mm. and the width from 0.7 to 1.0 mm. There are about 12 crochets on the ventral proleg.



Figs. 2-14. *Deilinea* spp. 2 and 3, Cuticle, fifth-instar larva, *D. erythemaria* Gn. 4, Egg, lateral view, *D. exanthemata bryantaria* Tayl. 5, Anal plate, right half, fifth-instar larva, *D. variolaria* Gn. 6, Labrum, right half, fifth-instar larva, *D. exanthemata bryantaria* Tayl. 7, Head, frontal aspect, left half, fifth-instar larva, *D. variolaria* Gn. 8, Ventral aspect of pupa, female, *D. variolaria* Gn. 9, Dorsal aspect of posterior end of pupa, female, *D. variolaria* Gn. 10, Crochet arrangement on ventral proleg of fifth-instar larva, *D. borealis* H1st. 11, Prothoracic claw of fifth instar larva, *D. exanthemata bryantaria* Tayl. 12, Inner aspect of right mandible, first-instar larva, *D. borealis* H1st. 13, Inner aspect of right mandible, fifth-instar larva, *D. exanthemata bryantaria* Tayl. 14, Hypopharynx of fifth-instar larva, *D. exanthemata bryantaria* Tayl.

Fourth Instar: The head is pale green or pale russet with a dark lateral line on each parietal lobe and no dusky marking along the epicranial stem. The thorax and abdomen are green. The middorsal line of *D. borealis* is dark green, of *D. erythemaria*, it is grey, dark at the intersegmental regions, of *D. exanthemata bryantaria*, it is a purple dash at the anterior end of each of the first eight abdominal segments, with a flanking purple dash on the first five segments, and of *D. variolaria*, it is concolourous. The subdorsal line is white or cream-coloured in all species. There is a fine cream or white supraspiracular line in *D. borealis* and *D. exanthemata bryantaria*. The subspiracular line of *D. borealis* is white, occasionally with grey or brown shading ventrally; in *D. erythemaria* this line is brown or black, widened below the spiracles; the subspiracular line of *D. exanthemata bryantaria* is purplish-grey, widest below the spiracles; and in *D. variolaria* this line is brown and also widened below the spiracles. The midventral line is pale brown, cream or white.

The width of the head varies from 1.00 to 1.11 mm. in *D. variolaria* to as much as 1.55 mm. in *D. erythemaria*. The length of the body varies from 13 to 18 mm. and the width from 1.0 to 1.5 mm. There are from 14 to 16 crochets on each ventral proleg.

Fifth Instar: The heads of *D. borealis*, *D. erythemaria*, *D. exanthemata bryantaria*, and of the green phase larvae of *D. variolaria* have similar colour patterns. The ground colour is russet-green or yellow-green: there is a dark brown or red-brown bar on the lower side of each parietal lobe. In the brown phase of *D. variolaria* the ground colour is pale brown; the frons and epicranial stem are white; the clypeus is brown and the parietal lobes are lined with brown, the last line corresponding to the bar found on the other larvae.

The antennae of *D. variolaria* and *D. borealis* are brown; those of *D. exanthemata bryantaria* are brown or rose-coloured, and those of *D. erythemaria* are pale at the base and pink at the tips.

The thorax and abdomen are pale green or pale yellow-green and, in the brown phase of *D. variolaria*, pale brown. The middorsal line is green in *D. borealis* and *D. erythemaria;* in the latter there are often segmental red dashes at the anterior edge of abdominal segments one to eight, inclusive, with a flanking red dash in the addorsal region. Dyar (1903) does not mention these red marks but all six of his inflated larvae have them (Fig. 17). The middorsal line of *D. exanthemata bryantaria* is grey, with a purple or black dash at the anterior edge of each abdominal segment. The middorsal line of the green phase of *D. variolaria* is grey-green and of the brown phase, a series of grey dashes. The subdorsal line is pale in all species. There are usually two grey lines in the subdorsal region of the larvae of *D. variolaria*. The subspiracular line of *D. borealis* is grey or green; in *D. erythemaria* it may be pale green or a series of segmental rose-coloured or brown patches, connected by a faint rose or pale brown line; the subspiracular region of *D. exanthemata bryantaria* is rose-coloured or has a wide purple brown line on the prothorax and pale purple patches on the mesothorax, metathorax, and each of abdominal segments 1 to 8, inclusive; in the green phase of *D. variolaria* there is a broad grey-green line and in the brown phase, grey lines (Fig. 19). The midventral line is pale in all species.

The thoracic and anal plates are concolourous with the remainder of the body; the anal plate may have grey or white mottling. The legs are concolourous with the body also; the prolegs have a dark patch of colour on each leg.

From 15 to 20 fifth-stage larvae were measured in each species. The head width of *D. variolaria* varies from 1.52 to 1.75 mm., of *D. borealis*, from 1.60 to 1.90 mm., and of *D. erythemaria* and *D. exanthemata bryantaria*, from 1.67 to 2.00 mm. The length of the body varies from 14 to 30 mm. The width of the body varies from 1.3 to 2.5 mm. There are from 15 to 19 crochets on each ventral proleg.

Systematic Position

The larvae of *Deilinea* are placed in the Ennominae on the basis of: seta L-4 present on abdominal segments 2, 3, 4, and 5 (Figs. 16-19), abdominal segment 1 with seven long setae in L, SV, and V groups and with setae SV-1, SV-2, and V-1 in, or almost in, a straight line (Fig. 16), first five abdominal segments with four to eight annulets, and anal plate with setae D-1 considerably posterior to line between setae SD-1 (Fig. 5). The crochets are interrupted, that is, in two groups (Fig. 10), the anal shield is pointed (Fig. 5) and the cuticle is smooth, or almost smooth (Figs. 2 and 3).

Key to fifth-instar larvae of *Deilinea*

1. Larvae brown, often with grey markings (Fig. 19) ..... (brown phase) *D. variolaria*
   Larvae green 2
2. Larvae with black, red, or purple markings on thorax and abdomen 3
   Larvae without red or purple markings on the thorax and abdomen 4
3. A black or purple middorsal dash at anterior edges of first few abdominal segments; occurs in western Canada ..... *D. exanthemata bryantaria*
   Three red or purple middorsal dashes at anterior edge of first few abdominal segments (Fig. 17); occurs across Canada ..... *D. erythemaria*
4. Grey-green middorsal and subspiracular lines ..... (green phase) *D. variolaria*
   No grey-green middorsal or subspiracular lines ..... *D. borealis*
   D. erythemaria

Notes on Other Stages

Egg

The eggs of *Deilinea* are elongate, with one end flattened and the other rounded (Fig. 4). The eggs of *D. exanthemata bryantaria*, *D. erythemaria*, and *D. variolaria* have a number of low, longitudinal ridges on the surface. These ridges are lacking in *D. borealis*. The egg size is about 0.8 mm. by 0.6 mm. by 0.4 mm. and varies little between species.

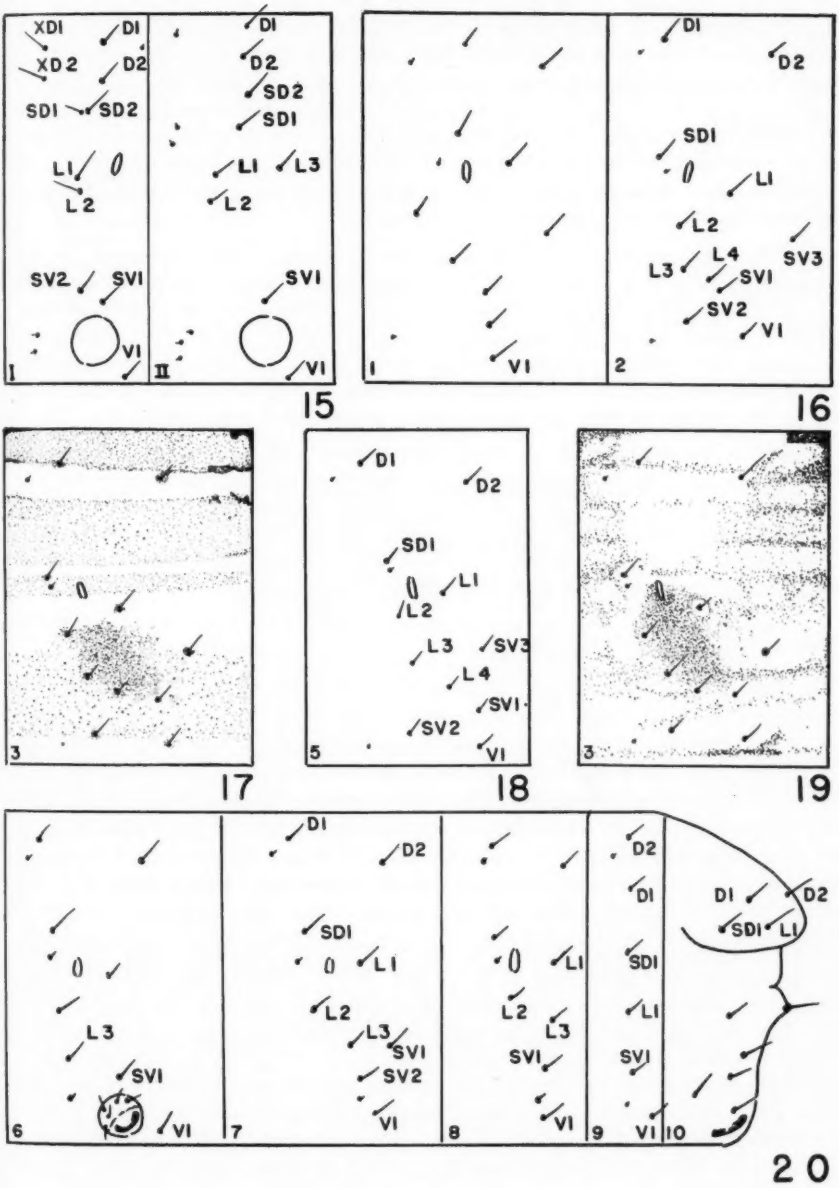
The colour varies. Dyar (1903) notes that the eggs of *D. erythemaria* are dull bluish-green. These eggs probably turn red before hatching since I have seen red eggs of this species. Rindge (1956) indicates that the eggs of *D. variolaria* are light green when first laid and red before hatching. In *D. borealis* and *D. exanthemata* the eggs are yellow at first but later become speckled with red in the former and entirely red in the latter.

Pupa

Except for size, there is little or no specific difference in the pupae of *Deilinea*. They are shiny brown in colour. There is a distinct furrow on the dorsum between segments 9 and 10. The cremaster has eight recurved spines (Figs. 8 and 9). The length of the pupa varies from 7.0 mm. in *D. borealis* to 11.0 mm. in *D. exanthemata bryantaria* and *D. erythemaria*.

Life History and Habits

Forest Insect Survey records indicate that all the Canadian species of *Deilinea* occur in Alberta. Larvae collected at many different points (Fig. 1) have been reared to the adult stage at Seebe. *D. borealis* and *D. exanthemata bryantaria* have been collected in the mountains and foothills and *D. variolaria* and *D. erythemaria* in the parkland and forested region of the north. Three of the four species occur near Grimshaw, in northwestern Alberta.



Figs. 15-20. Setal and colour patterns of fifth-instar larvae. 15, Prothorax and mesothorax, *D. variolaria* Gn. 16, First and second abdominal segments, *D. variolaria* Gn. 17, Third abdominal segment, *D. erythemaria* Gn. 18, Fifth abdominal segment, *D. exanthemata bryantaria* Tayl. 19, Third abdominal segment, brown phase, *D. variolaria* Gn. 20, Sixth to tenth abdominal segments, *D. variolaria* Gn.

I was stationed at Seebe in 1955 and 1956 and took advantage of this opportunity to make some notes on the *Deilinea* there. The Canadian species hibernate as pupae so I encountered the adult stage first, then the egg, and in due course, the larval and pupal stages. I saw and collected only three adults (all females) of *D. borealis* but I secured a large number of *D. exanthemata bryantaria* (both sexes). Gravid females from each of these species were caged in an insectary. From these I got two clutches of eggs in each species. The notes on adult oviposition and larval feeding habits are based on observations of these moths and their progeny in the insectary.

The adults of *D. borealis* were on the wing about the time most of the bud scales had fallen off white spruce (June 20 and 21 in 1955 and June 3 in 1956). The adults of *D. exanthemata bryantaria* flew from the middle of June until the end of July. The former flew early in the afternoon (12.30-3.00 p.m.) and held their wings upright over the body when at rest. *D. exanthemata bryantaria* flew from 3.30 p.m. until after dusk, when they could be attracted to lights. When at rest they spread their wings out to the side.

The oviposition habits of these two species were different. *D. borealis* laid a total of 15 to 41 eggs singly or in clumps of as many as nine in various places on the lower surface of a willow leaf. The eggs of *D. exanthemata bryantaria* were laid singly along the midrib on the lower surface of the leaf. The number of eggs varied from 9 to 15. After oviposition the moths of both species may live for a few days without any food except water.

The eggs of *D. exanthemata bryantaria* hatched in 5 to 13 days and the eggs of *D. borealis* in 15 to 16 days.

The larvae wandered around for as much as a day or more after hatching. Young larvae skeletonized the lower surface and mature larvae ate patches from the leaf of willow. They dropped readily when disturbed and hung by threads. When feeding or resting the larvae were usually stretched out along the leaf. After passing through five stages the larvae reached maturity in 27 to 35 days.

D. borealis and *D. erythemaria* feed from the middle of June until August or even September and *D. exanthemata bryantaria* and *D. variolaria* commence feeding in July and may not pupate until September. When fully fed the larvae tie leaves together with silk and pupate within this shelter.

Although all four species feed on willow, mature larvae also eat aspen (Forbes, 1948 and Raizenne, 1952). The British species also feed on alder and birch (Stokoe and Stovin, 1948). In New York, Rupert (*in litt.*) reports that he was unable to induce larvae of *D. erythemaria* to eat willow but they would eat aspen. Among the aspen groves of the hill country there he found only *D. erythemaria* but among the willow of the river flats he found *D. variolaria.* Both species of *Deilinea* occurred where both hosts grew. These observations of Rupert, coupled with my own, indicate that a critical examination of the food habits of *Deilinea* should be made at various points across North America.

Acknowledgments

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(Received May 13, 1957)

Parasitism of the European Pine Sawfly, *Neodiprion sertifer* (Geoff.) (Hymenoptera: Diprionidae), in Southwestern Ontario[1]

By L. R. Finlayson and Thelma Finlayson[2]
Entomology Laboratory, Belleville, Ontario

Cocoons of *Neodiprion sertifer* (Geoff.) were collected in southwestern Ontario in 1941, 1943, 1946, 1947, and 1949 for experimental investigations at the Belleville laboratory. A total of 8,326 cocoons were collected, mainly within about eight miles northeast and east of Sarnia, Ont., but a few were collected at Strathroy and Brigden, Ont. Each cocoon was incubated separately in a small vial so that each parasite could be associated with the host cocoon from which it emerged. Sawflies emerged from 68 per cent of the cocoons and parasites from 12 per cent; dissection of the remaining cocoons showed 16 per cent contained dead sawfly larvae and pupae, and four per cent dead parasite larvae.

Eleven species of parasitic Hymenoptera and three of Diptera were reared. The Hymenoptera were: *Agrothereutes* sp., *Aptesis basizonia* (Grav.), *Aptesis indistincta* (Prov.), *Dahlbominus fuscipennis* (Zett.), *Delomerista diprionis* Cush., *Endasys subclavatus* (Say), *Euceros frigidus* Cress., *Eupelmella vesicularis* (Retz.), *Exenterus abruptorius* (Thunb.), *E. canadensis* Prov., and *Mastrus argeae* (Vier.). The Diptera were: *Hemipenthes sinuosa* (Wied.), *Neophorocera hamata* (A. & W.), and *Spathimeigenia erecta* Ald. The percentage of parasitism for these collections were: 9.0 per cent in 1941; 6.2 per cent in 1943; 19.3 per cent in 1946; 20.6 per cent in 1947; and 46.9 per cent in 1949. The relative abundance of the parasites in each year is shown in Table I.

Three of the species found are not native to Canada, namely: *A. basizonia*, *D. fuscipennis*, and *E. abruptorius*. Releases of these three species were made in the Sarnia area in 1941-1947 from material that originated in Europe. The recovery of *E. abruptorius* is the first record of establishment of this species in Canada, as far as we know. In Europe this is an important parasite of *N. sertifer*. Though *A. indistincta* is a native parasite, it was propagated at Belleville from

[1]Contribution No. 3653, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.

[2]Assistant Entomologist and Technical Officer.

TABLE I

Percentage parasitism of cocoons of *N. sertifer* in southwestern Ontario for five years

From 626 cocoons collected in 1941	From 2,308 cocoons collected in 1943	From 1,892 cocoons collected in 1946	From 3,225 cocoons collected in 1947	From 275 cocoons collected in 1949
D. fuscipennis.....3	*E. canadensis*.....1.6	*D. fuscipennis*.....9.5	*E. canadensis*.....6.8	*H. sinuosa*.....12
E. canadensis.....2	*E. subclavatus*.....1.6	*H. sinuosa*.....4.5	*D. fuscipennis*.....3.0	*E. subclavatus*..... 6
N. hamata.....2	*D. fuscipennis*.....0.6	*E. canadensis*.....2.7	*E. subclavatus*.....1.5	*E. canadensis*..... 3
A. basizonia.....1	*E. abruptorius*.....0.2	*E. subclavatus*.....1.0	*H. sinuosa*.....0.4	*D. fuscipennis*..... 1
H. sinuosa.....0.3	*E. frigidus*.....0.1	*A. basizonia*.....0.4	*A. basizonia*.....0.2	*M. argeae*..... 1
M. argeae and *E. subclavatus*.1	*H. sinuosa*.....0.1	*M. argeae*.....0.3	*N. hamata*.....0.1	
		D. diprionis.....0.2	*E. vesicularis*.....0.1	Unidentified (Dead larvae and pupae).....24
	Unidentified (Dead larvae and adults).....2.0	*E. abruptorius*.....0.2	Unidentified (Dead larvae and pupae).....8.5	
		A. indistincta.....0.1		
		Agrothereutes sp.....0.1		
		E. frigidus.....0.1		
		N. hamata.....0.1		
		S. erecta.....0.1		

stock that originated in New Brunswick and was released in the Sarnia area in 1942. The specimens reared may or may not represent recoveries.

The parasites were identified by Dr. W. R. M. Mason, Mr. G. E. Shewell, and Mr. G. S. Walley, Insect Systematics and Biological Control Unit, Entomology Division, Ottawa.

(Received June 19, 1957.)

Effect of Area of Search on Reproduction of *Encarsia formosa* Gahan (Hymenoptera: Chalcidoidea)[1]

By T. BURNETT[2]
Entomology Laboratory, Belleville, Ontario

In an earlier laboratory study (Burnett, 1958) influences of various types of host distribution on the efficiency of the chalcid parasite *Encarsia formosa* Gahan were determined. A constant number of parasites searched among five host densities for scales of the greenhouse whitefly, *Trialeurodes vaporariorum* (Westw.), that were distributed in three patterns over a 25-square-inch surface. In addition to the increased parasitism resulting from contagious distributions of the host, it was found that approximately the same percentage of each of the five different host densities within the same distribution was attacked by the parasite.

The fact that a relatively constant percentage of the hosts was parasitized is of interest for it suggests that the parasite females covered a certain percentage of the experimental area and attacked hosts present within this area. The same result would obtain, however, if only a given percentage of the hosts were acceptable to the parasite and all hosts were easily found by *Encarsia* females. This is not likely because there were differences in the level of parasitism when the same number of hosts was arranged in different patterns. At the same time, the acceptability of the host must have influenced the results for the fecundity of the parasite was only one-half of its potential at the highest host density.

The influences of host acceptability by the parasite females and of the ability of the females to find hosts may be examined by varying the area over which a constant number of parasites search for various numbers of host scales. In this way the properties and ratios of hosts and parasites remain the same; if these factors are dominant the results should be much the same when different areas are used. But the density of parasites varies with area and the density of hosts varies within and between areas; if these factors operate the percentage of parasitized hosts should vary with area but remain much the same within a given area.

This paper deals with the influence of the area of host distribution on the reproduction of the parasite *Encarsia formosa* when a constant number of parasites search for various numbers of scales of the greenhouse whitefly *Trialeurodes vaporariorum*. The technique used in these experiments was described previously Burnett, 1958). Twenty females of *Encarsia* searched among five numbers of hosts, i.e. 4, 16, 36, 64, and 100, distributed uniformly over experimental areas of

1Contribution No. 3662, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.

2Senior Entomologist.

TABLE I

The reproduction of *Encarsia formosa* when 20 female parasites searched for various numbers of hosts distributed uniformly over 25, 100, and 200-square-inch areas

	Area	Number of Hosts Exposed				
		4	16	36	64	100
Replicates		20	15	10	10	10
No. of Hosts Parasitized	25	3	14	32	54	84
	100**	2	10	28	48	72
	200***	2	8	24	40	63
No. of Parasite Eggs Laid	25	8	28	81	113	166
	100**	5	18	55	79	112
	200***	3	14	41	59	90
Percentage of Hosts Parasitized	25	83	88	88	85	84
	100	60	65	78	74	72
	200	40	53	68	63	63
No. of Eggs Per Host	25	1.9	1.8	2.2	1.8	1.7
	100	1.1	1.1	1.5	1.2	1.1
	200	.7	.9	1.1	.9	.9
No. of Eggs Per Parasitized Host	25	2.3	2.0	2.5	2.1	2.0
	100	1.9	1.7	2.0	1.7	1.6
	200	1.8	1.7	1.7	1.5	1.4
Difference: Observed-Random Parasitism of Hosts Exposed	25	.1	.8*	−.3	1.7*	2.7
	100	−.1	−.2	−.1	2.2*	4.9*
	200	−.3	−.7	.1	1.8	3.2*

*Difference of observed-calculated means significant at 5% level.
**Means differ from those for 25 square inch area at 5% level of significance.
***Means differ from those for 100 square inch area at 5% level of significance.

25, 100, and 200 square inches. The number of replicates at each host density is given in Table I.

Results

The numbers of hosts parasitized by 20 females of *E. formosa* are given in Table I and shown in Fig. 1. The relation of parasitism to host density was either slightly curvilinear (25 and 100-square-inch areas) or almost so (200-square-inch area; $P = 0.05$); but the sums of squares attributable to linear regressions accounted for at least 99.8 per cent of those of the density means. In this case, the relation of the number of hosts parasitized to the number exposed is described sufficiently accurately by a linear regression. The relation is also indicated by the variation in percentage parasitism on the two larger experimental areas. With increase from the lowest to the middle density, the percentage of hosts attacked became larger, whereas from the median density to the upper limit it remained much the same. This trend is shown in Fig. 1, where the observed values vary to a limited extent about the regression lines for the 100 and 200-square-inch areas in a regular manner.

The area over which the hosts were distributed affected the level of parasitism. With a given number of hosts and 20 parasites, the number of hosts parasitized was significantly less as the area was increased (Table I). The rate at which the parasites found hosts with increase in host density diminished significantly as the experimental area was enlarged from 25 to 100 square inches ($F = 23.66$; d.f. = 1, 6; $P < 0.01$) and from 100 to 200 square inches ($F = 13.01$;

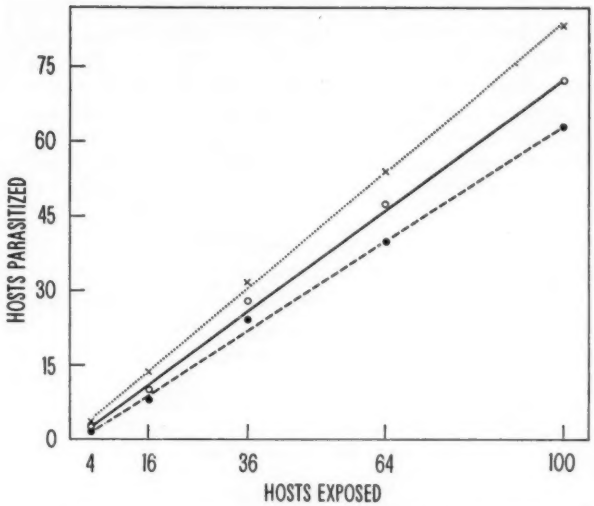

Fig. 1. The relation of the number of hosts parasitized to the number of hosts exposed when 20 females of *Encarsia formosa* searched for scales of the greenhouse whitefly distributed uniformly over 25, 100, and 200 square-inch areas. 25 square-inch area, dotted line $y = 37.44 + 0.84$ (x-44); 100 square-inch area, solid line $y = 32.12 + 0.73$ (x-44); 200 square-inch area, broken line $y = 27.54 + 0.64$ (x-44).

d.f. = 1, 6; $P<0.05$). It is surprising to note from Table I that as the area was enlarged eight times, the parasitism decreased at the most from 80 to 40 per cent and usually only from 80 to 60 per cent. Evidently a many-fold increase in the experimental area is required to reduce appreciably the area actually examined by the parasite population.

The numbers of parasite eggs laid by 20 female *Encarsia* when searching among 4, 16, 36, 64, and 100 scales of *T. vaporariorum* distributed over 25, 100, and 200 square-inch surfaces are given in Table I and shown in Fig. 2. The number of eggs deposited by the parasites increased as more hosts were exposed on each experimental area but there was relatively greater oviposition at the middle density; as shown in Table I, the number of eggs per host and the number of eggs per parasitized host were generally at a maximum when 36 hosts were exposed. Though the relation of oviposition to host density was the same on each of the three areas, the level of oviposition was significantly decreased as the area was enlarged.

The distribution of the eggs of *Encarsia* among the scales gives some indication of the influence of area on the searching activities of the parasite. In Table I the average number of hosts parasitized was compared with the number that would result from a random distribution of parasite eggs as determined by Thompson's (1939) formula,

$$Y = N\,(1\text{-}e^{-X/N}),$$

where Y = the number of hosts parasitized, N = the number of hosts exposed, X = the number of parasite eggs laid, and e = the base of natural logarithms. Though the differences listed in Table I were not usually significant, a systematic trend, as host numbers and area were varied, in the distribution of parasite progeny was indicated. As the number of hosts exposed increased from the middle density,

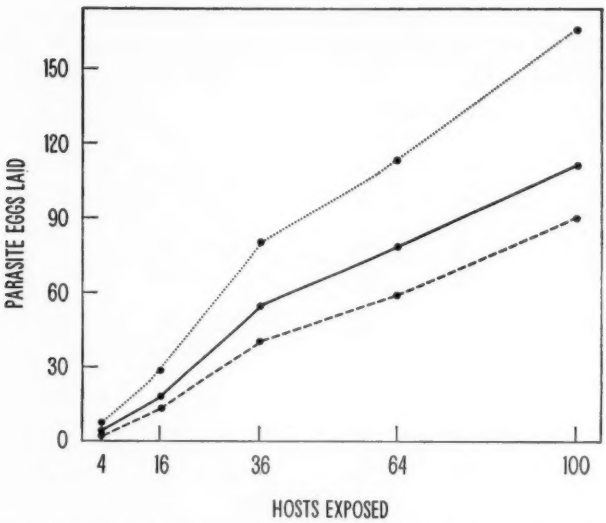

Fig. 2. The relation of the number of parasite eggs laid to the number of hosts exposed when 20 females of *Encarsia formosa* searched for scales of the greenhouse whitefly distributed uniformly over 25, 100, and 200 square-inch areas. 25 square-inch area, dotted lines; 100 square-inch area, solid line; 200 square-inch area, broken line.

the parasite appeared to avoid parasitized hosts to an increasing extent. On the two larger areas it tended to concentrate its progeny in some hosts at the lower host densities. An unusual feature of the pattern of distribution was the trend on the 25-square-inch area, where the parasite oviposited in more hosts than would result from a random distribution of eggs except at the median density.

Conclusions

In the present experiments 20 females of *Encarsia formosa* searched for five numbers, ranging from 4 to 100, of hosts distributed uniformly over three areas. In this case the ratio of hosts to parasites remained constant for a given number of hosts exposed, but the density of the host and parasite varied. In the experiments all measures of parasitism (the number of hosts parasitized, the number of parasite eggs laid, the number of eggs per host exposed) decreased for a given number of hosts exposed as the area was enlarged. Therefore, although the number of hosts parasitized is related to the number exposed, the parasitism of *T. vaporariorum* by *E. formosa* is not independent of the area of host distribution.

On any given experimental area the parasites found increasing numbers of hosts as host density was increased. On the two larger areas the percentage of hosts parasitized increased with initial increase in host density, and with further increase in host density it remained approximately a constant. On the 25-square-inch area the parasites found hosts in proportion to the number exposed. This relationship also existed in previous experiments (Burnett, 1958) in spite of the reduction of parasite fecundity to about one-half of the present level. As the same general trend occurred at two distinctly different levels of parasitism, it is probable that an underlying process operated on the manner in which the parasite searched the environment.

An over-simplified description of the searching of *Encarsia* is that a constant number of parasites covered a certain portion of a given experimental area and

parasitized hosts that were present in this portion. This explanation must be modified by the fact that on the larger areas increasing proportions of hosts were attacked as very low host densities were increased. In addition, the parasitism of the host was modified by the manner in which the parasite distributed its progeny. More hosts than would result from a random distribution of parasite progeny were attacked when larger numbers of hosts were exposed. In view of the apparent concentration of parasite eggs in some hosts, however, it is not certain that the parasite avoids parasitized hosts. This problem will be further investigated.

Acknowledgments

The author expresses his appreciation to Dr. W. R. Thompson for reading the manuscript and to Mr. G. D. Williamson for technical assistance.

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Notes on Life-Histories of Sawflies (Hymenoptera: Tenthredinidae) Common in Low-bush Blueberry Fields in New Brunswick[1]

By W. T. A. Neilson[2]

Fruit Insect Section, Entomology Laboratory, Fredericton, New Brunswick

Neilson (1955) listed 19 species of sawflies collected from low-bush blueberry fields in New Brunswick. However, most of the listed species are either scarce or transient. This paper embodies notes on the life-histories, seasonal development, and parasites of the common species, *Neopareophora litura* (Klug), *Pristiphora bivittata* (Nort.), *P. idiota* (Nort.), *Pristiphora* sp., and two species of *Nematus*. The data were obtained from field collections and insectary rearing. Keys are provided for identification of the immature stages.

According to Dr. R. Lambert (in litt.), Entomology Division, Ottawa. *Pristiphora* sp. may be new, and, until the genus is revised, cannot be specifically determined. Similarly, the two species of *Nematus* cannot be specifically identified, and in this paper are referred to as *Nematus* (*Pontania*) sp. 1 and *Nematus* (*Pontania*) sp. 2.

Identification of Immature Stages

Egg

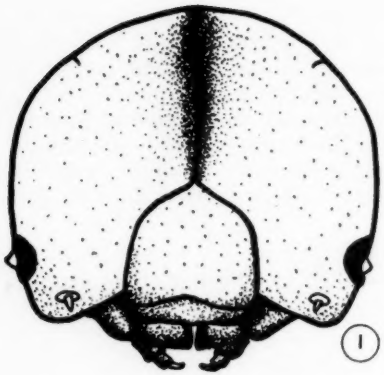
The eggs of all the species are kidney-shaped except that of *Nematus* (*Pontania*) sp. 2, which is ovoid.

Key to Eggs

I. Eggs on blueberry
  1. Laid within the leaf bud; average length 1.00 mm., width 0.27 mm. ..... *Neopareophora litura*
  2. Laid at the edge of the leaf
    (i) Beneath the upper epidermis; average length 1.18 mm., width 0.61 mm. ..... *Pristiphora idiota*
    (ii) Beneath the lower epidermis; average length 1.30 mm., width 0.56 mm. ..... *Pristiphora* sp.

1Contribution No. 3666, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.

2Assistant Entomologist.



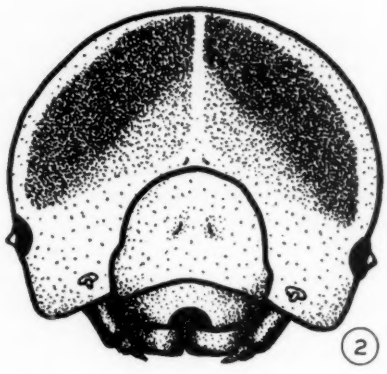


Fig. 1. Head shield of *Pristiphora bivittata* (Nort.).
Fig. 2. Head shield of *Pristiphora* sp.

II. Eggs on meadow-sweet; at the edge of the leaf beneath the lower epidermis; average length 0.94 mm., width 0.37 mm. ..... *Pristiphora bivittata*
III. Eggs on poplar; beneath the epidermis near the posterior edge of the leaf; the distal end of the leaf is folded over the egg; average length 0.74 mm., width 0.33 mm. ..... *Nematus* (*Pontania*) sp. 1
IV. Eggs on rhodora; in a slit on the ventral surface of the midrib; average length 0.92 mm., width 0.49 mm. ..... *Nematus* (*Pontania*) sp. 2

Larvae

On the basis of colour and head-shield patterns, the mature larvae may be identified with the following key.

Key to Mature Larvae

I. Larvae in which the alimentary canal is visible through the epidermis as a continuous dark-green mid-dorsal line.
  1. Dorsum with a white stripe on each side of the canal
    (i) Larvae green; length 13-15 mm.
      (a) Brownish-black markings on the head-shield parallel to the epicranial suture (Fig. 1); host: meadow-sweet ..... *Pristiphora bivittata*
      (b) Brownish-black marking on head shield not parallel to the epicranial suture (Fig. 2); host: blueberry ..... *Pristiphora* sp.
    (ii) Larvae red; black markings mid-dorsally on thoracic segments; length 13-15 mm.; Host: blueberry ..... *Pristiphora idiota*
  2. Dorsum without a white stripe on each side of the canal
    (i) Larvae grass-green or pink; length 9-11 mm.; host: blueberry ..... *Neopareophora litura*
II. Larvae in which the alimentary canal is not visible through the epidermis.
  1. Larvae pale green; length 4-5 mm., pair of suranal protuberances; host: poplar ..... *Nematus* (*Pontania*) sp. 1
  2. Larvae light shining green; length 11-13 mm.; enlarged thoracic segments; prominent dark setal tubercles; host: rhodora ..... *Nematus* (*Pontania*) sp. 2

The larvae of *N. litura*, as noted in the above key, are either green or pink without intermediate gradations. Pink larvae were scarce and each year consisted of 6-10 per cent of the total collected.

Each of the species has well-defined instars without overlapping of head-shield measurements (Table I).

Seasonal Histories

Neopareophora litura, Pristiphora idiota, Nematus sp. 1 and *Nematus* sp. 2 have only one generation a year. Franklin (1948) reported *P. idiota* as having

TABLE I

Head-Shield Measurements (mm.) of Six Species of Sawfly Larvae

	Instar				
	I	II	III	IV	V
Neopareophora litura					
No. measured	29	16	56	56	
Range	0.29–0.33	0.45–0.49	0.64–0.74	0.87–0.99	
Mean	0.32	0.47	0.69	0.92	
Pristiphora bivittata					
No. measured	16	15	20	32	43
Range	0.40–0.45	0.54–0.61	0.64–0.95	1.02–1.22	1.28–1.56
Mean	0.42	0.58	0.83	1.16	1.41
Pristiphora idiota					
No. measured	32	30	30	30	
Range	0.46–0.55	0.65–0.75	0.80–1.02	1.09–1.19	
Mean	0.51	0.70	0.93	1.14	
Pristiphora sp.					
No. measured	22	22	30	66	
Range	0.44–0.49	0.61–0.73	0.86–1.09	1.15–1.51	
Mean	0.46	0.67	0.97	1.34	
Nematus (*Pontania*) sp. 1					
No. measured	10	10	10	8	
Range	0.31–0.32	0.42–0.46	0.61–0.68	0.77–0.83	
Mean	0.32	0.44	0.64	0.80	
Nematus (*Pontania*) sp. 2					
No. measured	10	7	7	6	6
Range	0.36–0.41	0.53–0.58	0.72–0.85	1.01–1.09	1.15–1.27
Mean	0.38	0.55	0.81	1.05	1.24

about five generations a year on cranberry in Massachusetts. *Pristiphora bivittata* and *Pristiphora* sp. usually have only one generation a year, but in a few years they had a partial second or a complete second and a partial third generation.

The larvae of all the species overwinter within cocoons, which are spun at a depth of two to three inches in the litter layer beneath the plants. Particles of dead leaves often adhere to the sides of the cocoon.

The overwintered larvae change rapidly to prepupae shortly before the adults emerge. The characteristics of this stage are the formation of the compound eyes above the ocelli and the shrivelled appearance of the larval body. Immediately after the prepupal changes have taken place, a creamy-white pupa is formed which gradually assumes the colour and characteristics of the adult. The time required to complete development from prepupa to adult is one to two weeks.

The emergence period varies with the species and the season. The adults of *N. litura* appear from early to late May, those of *Pristiphora bivittata*, *Pristiphora* sp., *Nematus* sp. 1, and *Nematus* sp. 2 from mid May to early June, and those of *P. idiota* from the middle of August to early September. When a partial second generation of *P. bivittata* or *Pristiphora* sp. occurred the adults appeared from early July to late August. When a complete second and a partial third generation occurred, the second appeared in July and the third in late August.

The females of all the species are parthenogenic and begin oviposition immediately after emergence. With the exception of *Nematus* spp., males were very scarce, and mating was not observed in the field or in oviposition cages. Oviposition records showed that most of the eggs were laid during the first four days after emergence. The maximum numbers of eggs laid by *N. litura*, *P. bivittata*, *P. idiota*, and *Pristiphora* sp. were 32, 95, 42, and 66 respectively. Dissection of the ovaries showed that usually only three-fourths of the egg complement was oviposited. In cages several eggs were laid in the same bud or on the same leaf. Field observations showed that the eggs were usually laid singly on the host plants, i.e., one per bud or leaf.

The incubation period of the egg ranged from 5 to 11 days and was approximately the same for all the species.

The larvae begin feeding immediately after eclosion and are diurnal and nocturnal in feeding habit. The larva of *N. litura* feeds within the blueberry bud during the first instar, consuming all or a large portion of the bud. Subsequent instars feed at the edges of the leaves. *P. idiota* and *Pristiphora* sp. feed at the edges of the leaves, eating towards the midrib. Injured leaves have a scalloped appearance. *P. bivittata* feeds on meadow-sweet in a similar manner. Arnup (1955) reported this species as having caused light damage to nursery plants of *Spiraea vanhouttei* Zabel. The larva of *Nematus* (*Pontania*) sp. 2 eats small circular holes from rhodora leaves and also feeds at the edges of the leaves. The larva of *Nematus* (*Pontania*) sp. 1 feeds at first beneath the leaf fold, consuming the epidermal layer, but later leaves the fold and eats small circular holes in the leaves. This species feeds in a manner similar to that described by Cooley (1903) for the poplar leaf-folding sawfly, *Nematus* (*Pontania*) *bozemani*.

The length of the feeding period varied with the species. *Pristiphora* spp. fed for 5-6 weeks, whereas *N. litura* and *Nematus* spp. fed for approximately 4 weeks.

After reaching maturity the larvae drop to the ground and spin their cocoons in the loose duff and litter. Usually they hibernate within these cocoons for approximately ten months. However, in *P. bivittata* and *Pristiphora* sp., when a second or third generation occurred the hibernation period varied from two weeks to two months.

The life-histories of *N. litura*, *P. idiota*, and *Pristiphora* sp. in relation to the blueberry plant development are shown in Figure 3. That of *P. bivittata* and the species of *Nematus* correspond to that shown for *Pristiphora* sp.

Natural Enemies

Only hymenopterous parasites were recorded from these sawflies, the following ichneumonids having been obtained during 1950 to 1955 from insectary rearings:

Neopareophora litura: *Polyblastus pedalis* (Cress.), *Exyston* sp., ?*Trematopygus* sp., *Rhorus* (*Cyphanza*) sp., and *Mesoleius* sp.

Pristiphora bivittata: *Polyblastus pedalis* (Cress.), *P. fulvilinealis* Hall, *Erromenus marginatus* Prov., *Eudiaborus vitticollis* (Cress.), *Exyston* sp., ?*Trematopygus* sp., *Mesoleius* sp. (possibly *pertinax* Davis), *Synomelix* sp., *Syndipnus rubiginosus* Wly., and *Hypamblys albopictus* (Grav.).

Pristiphora sp.: *Cteniscus clypeatus* (Cress.).

Dibrachys cavus (Wlkr.), a hyperparasite, was also reared, presumably from *P. pedalis*.

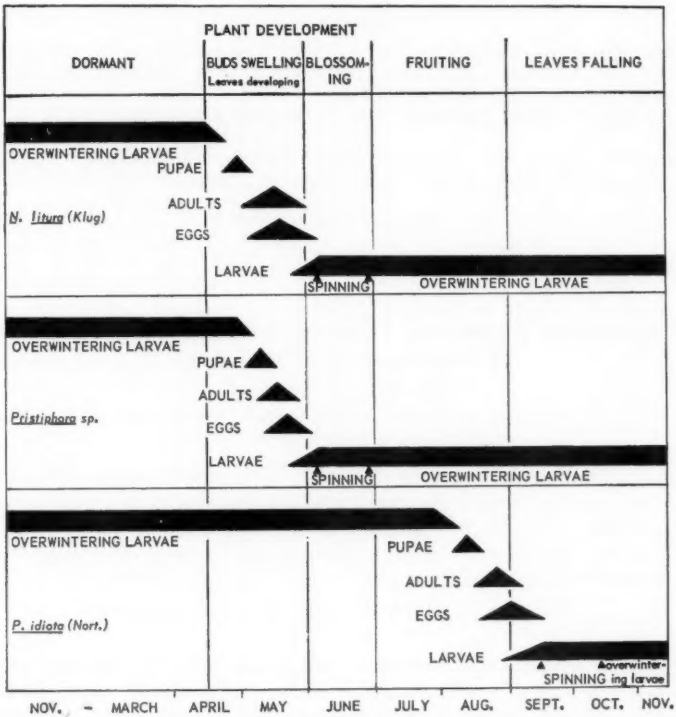


Fig. 3. Life-histories and seasonal development of *N. litura* (Klug), *Pristiphora* sp., and *P. idiota* (Nort.) in relation to the blueberry plant development.

Polyblastus pedalis and *Mesoleius* spp. were the most commonly reared parasites.

The life-history of *P. pedalis* closely parallels that of its host and rarely were there more than one generation a year. The egg is laid singly on the dorsal surface of the ultimate-instar larva, usually on the first thoracic segment. Oviposition occurs during the first three weeks of June. The host continues feeding and later spins the cocoon. The parasite overwinters as an egg on the host, hatches in the following spring, devours the larva, pupates within the host cocoon, and emerges as an adult in early June. The duration of the parasite within the host cocoon usually ranged from 333 to 365 days. However, in a few instances this period lasted for only 35 days.

The life-histories of the two species of *Mesoleius* are similar to that of *P. pedalis*.

Acknowledgments

The author wishes to acknowledge assistance from Mr. F. A. Wood, who drew the illustrations. He is also indebted to the following officers of the Entomology Division, Ottawa: Dr. R. Lambert, for identification of the adult sawflies; Dr. W. R. M. Mason, Dr. O. Peck, and Mr. G. S. Walley, for identification of parasites.

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(Received July 11, 1957.)

Pycnarmon jaguaralis (Guenée) and an Allied Species (Lepidoptera: Pyralidae)[1]

By EUGENE MUNROE[2]
Insect Systematics and Biological Control Unit
Entomology Division, Ottawa, Canada

The familiar species *Pycnarmon jaguaralis* (Guenée) ranges from the Himalayas to the Solomons and Queensland with comparatively little variation. Specimens from Buru, Obi, Luzon, Amboina and Waigeu seem hardly different from those from the Himalayas. In New Guinea and eastward a distinct subspecies occurs, which I describe as follows:

***Pycnarmon jaguaralis papualis*, new subspecies**

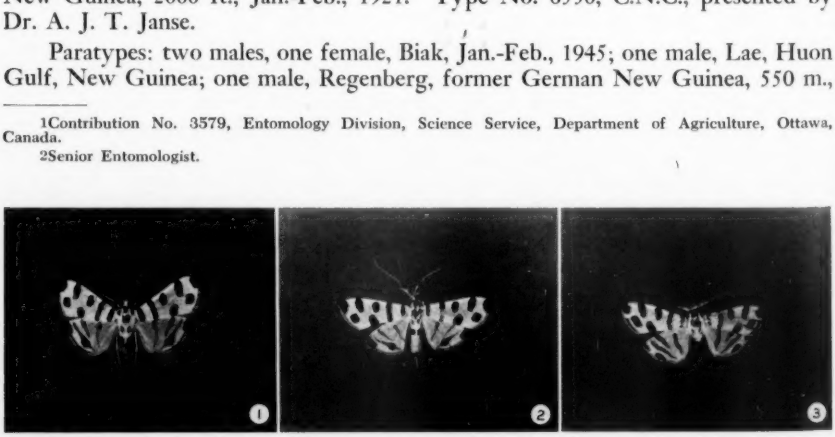
Figs. 1, 4

In general similar to the nominate subspecies (Fig. 2) but larger, the black markings of the wings on the average somewhat reduced, those of the body somewhat enlarged, especially the second pair of abdominal spots, which is usually much longer than in the nominate subspecies. Anal angle of hind wing usually with prominent orange-yellow suffusion, lacking in the nominate subspecies, obscuring the subterminal and terminal lines; the black transverse dash found in the anal angle of the nominate subspecies lacking in the present subspecies even when the yellow suffusion is absent.

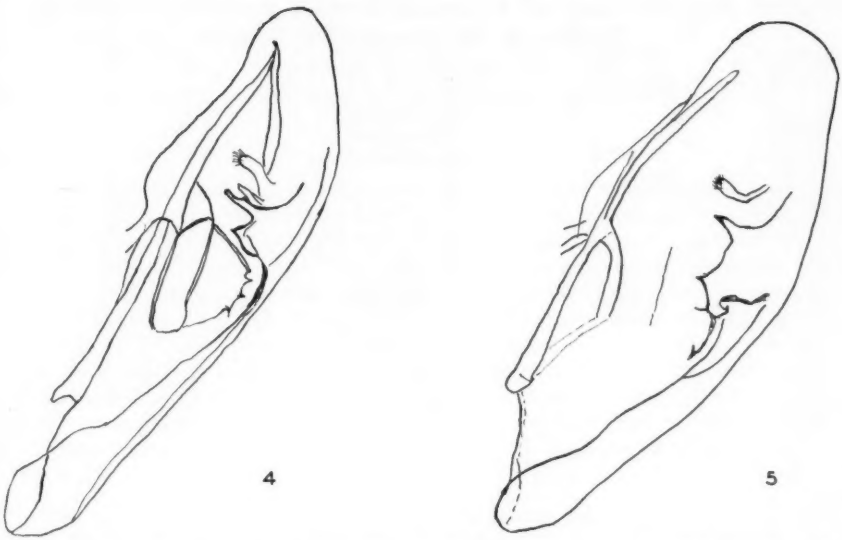
Holotype, male, and allotype, female, Nomnagihe, Geelvink Bay, Dutch New Guinea, 2000 ft., Jan.-Feb., 1921. Type No. 6530, C.N.C., presented by Dr. A. J. T. Janse.

Paratypes: two males, one female, Biak, Jan.-Feb., 1945; one male, Lae, Huon Gulf, New Guinea; one male, Regenberg, former German New Guinea, 550 m.,

1Contribution No. 3579, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.
2Senior Entomologist.



Figs. 1-3. *Pycnarmon* spp. 1, *P. jaguaralis papualis*; 2, *P. j. jaguaralis*; 3, *P. decipiens*.



Figs. 4, 5. *Pycnarmon* spp., right valve of male genitalia. 4, *P. jaguaralis papualis;* 5, *P. decipiens.*

May, 1913, Kaiserin-Augusta Fluss Exp.; one male, Fergusson I.; one male, St. Aignan; one male, Florida I.; one male, Mulgrave R., Cairns, Queensland. Paratypes distributed among: the C.N.C.; the British Museum (Natural History); the Rijksmuseum van Natuurlijke Historie, Leiden; the Berlin Museum; the Transvaal Museum, Pretoria; and the California Academy of Sciences.

***Pycnarmon decipiens*, new species**

Figs. 3, 5

Similar in general aspect to *P. jaguaralis jaguaralis*, differing in the following respects: antenna of male with a serrated fringe of scales, rather than a row of separate scale-teeth, following the sinus; fore wing with a distinct black wedge adjoining posterior half of outer margin, this marking absent in *jaguaralis*; hind wing with subterminal line straight, slightly tapering posteriorly, and without any expansion in the cubital field; a prominent semicircular spot on outer margin about the middle; male genitalia with tegumen somewhat narrower and less strongly sclerotized than in *jaguaralis*, and with the processes of the valve differently shaped (Fig. 5).

Holotype, male, Calumbogan, Mindanao, Philippine, Is., July-Aug., 1917.

Paratypes: two males, "Mendanao, Philippines".

Holotype and one paratype, No. 113, Carnegie Museum; the second paratype, No. 6531, C.N.C.

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Field Identification of Ambrosia Beetles Attacking Coniferous Timber in the Douglas-Fir Region

By NORMAN E. JOHNSON
Weyerhaeuser Timber Company, Forestry Research Center
Centralia, Washington

Introduction

Coniferous timber in the Douglas-Fir Region is commonly subject to attack by ambrosia beetles of the families Scolytidae and Platypodidae. In view of the variety and extent of damage there is need for a ready method of identifying the ambrosia beetles causing major losses. It is the purpose of this paper to present methods of identifying the genera of ambrosia beetles found in the Douglas-Fir Region, by the general body shape of the insect, the diameter of the tunnel the beetles bore and the shape of the wood borings which they eject from these tunnels. These methods were developed by the author from original work conducted at Corvallis, Oregon in 1955-56 as part of his master's thesis at Oregon State College. Kinghorn, in Canada, developed similar methods of distinguishing ambrosia beetle damage and recently published means of differentiating the work of *Gnathotrichus*, from *Trypodendron* (Kinghorn, 1957).

Studies on the economic importance of ambrosia beetles in the Douglas-Fir Region have concentrated in British Columbia where at least one species is considered a major forest pest.

Graham and Boyes (1950) report that in many areas the presence of ambrosia beetle tunnels or "pinholes" may reduce the market value of lumber as much as 50 per cent. In Washington and Oregon the intensity of attack by these wood-boring beetles appears to be somewhat less than reported in British Columbia. However it does not take many attacks to reduce lumber grade significantly.

The more common ambrosia beetles attacking conifers in the Pacific Northwest are: (1) *Platypus wilsoni* Swaine, (2) *Trypodendron lineatum* Oliver, (3) *Gnathotrichus sulcatus* Leconte, (4) *G. retusus* Leconte, and (5) *Xyleborus saxeseni* Ratz.[1]

Shape of Beetle

Ambrosia beetles may prove difficult to identify to species using standard keys. With the exception of one species, they belong to the homogeneous family Scolytidae which contains well over 100 species of bark beetles in the Northwest. However, if one knows that the beetle was collected from a small, 1/16 inch or less, round and often stained gallery in sound timber, it can be identified to genus by the general body shape as viewed with the unaided eye or with a hand lens (Figure 1).

Platypus wilsoni, the only species of Platypodidae occurring in western United States, is the longest ambrosia beetle in this area: measuring over 5 mm. It is distinguished by having the head visible when viewed from above and having the first segment of the tarsus longer than the others combined.

Trypodendron has divided eyes, a rare characteristic in Scolytidae. Its antennal club is solid; and body length is about 3.5 mm. *T. lineatum* has pale

[1] *Typodendron lineatum* Oliver is considered by S. L. Wood, Brigham Young University (personal correspondence with author) the accepted name for beetles previously known as *T. bivittatum* Kirby, *T. cavifrons* Mannerheim and *T. borealis* Swaine. *T. rufitarsis* Kirby is another species that may be encountered which is considered synonymous with *T. ponderosae* which Chamberlin (1939) records as occurring from British Columbia south to California. Prebble and Graham (1957) report that *Xyleborinus tsugae* Swaine attacks conifers in British Columbia. This species is synonymous with *Xyleborus saxeseni* Ratz.

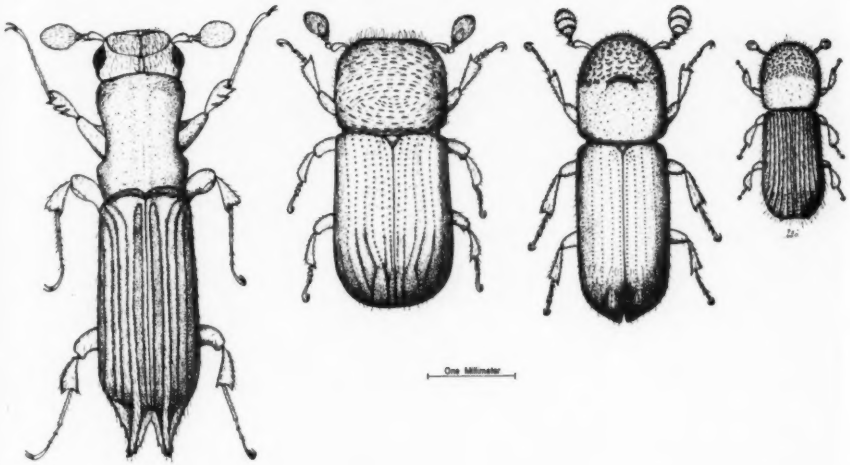

Fig. 1. General body shape is an aid in distinguishing ambrosia beetles: left to right *Platypus, Trypodendron, Gnathotrichus,* and *Xyleborus.*

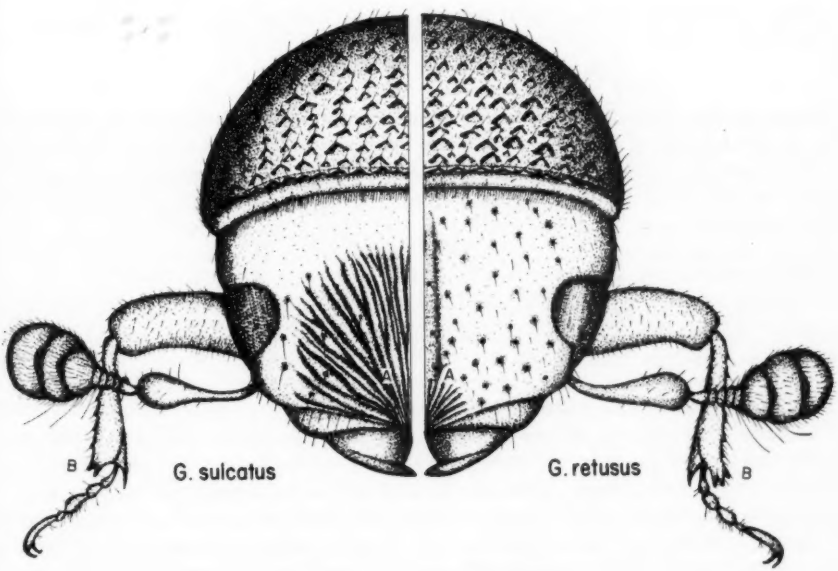

Fig. 2. The frontal diagram features two points of distinction for ambrosia beetles in the genus *Gnathotrichus*: *On left. G. sulcatus* has the frons with an extensive fan-shaped etching (A) and the fore tibia armed with two submarginal teeth (B); whereas *on right G. retusus* has a relatively smooth frons (A) and has tibia armed with three submarginal teeth (B).

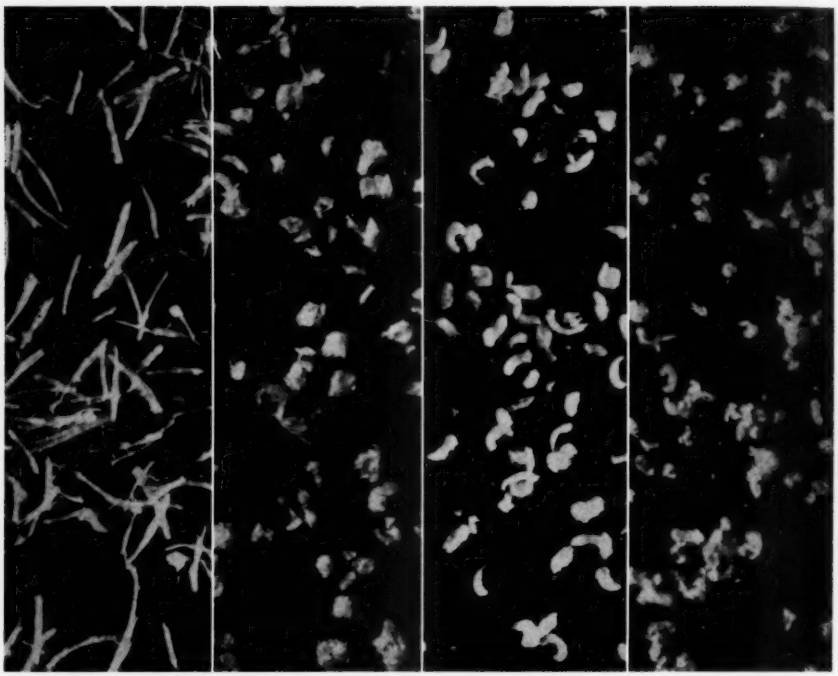

Fig. 3. Wood boring particles of ambrosia beetles. Left to right: *Platypus*, *Trypodendron*, *Gnathotrichus*, and *Xyleborus*. (X10)

stripes on the pronotum and elyta, which distinguishes it from the generally black *T. rufitarsis*.

Gnathotrichus has about the same body length as *Trypodendron*, but is more slender with a raised, curved, transverse ridge on the dorsal portion of the pronotum, and has a flattened antennal club with 3 equal segments. *G. retusus* can be distinguished from the more common *G. sulcatus* by the characters shown in Figure 2.

Xyleborus can be distinguished from *Gnathotrichus* by its smaller size and lack of the transverse ridge on the pronotum and its sub-oval antennal club which is segmented only terminally.

Character of Wood Borings

Since ambrosia beetles bore in the wood, *Platypus* often penetrating to the center of large logs, they are difficult to obtain as specimens for identification. When constructing their galleries, the adult beetles gnaw the wood with powerful mandibles. The wood particles are removed from the galleries and little piles of boring dust collect in bark crevices below the entrance. Three important genera of ambrosia beetles can be distinguished readily by the size and shape of these particles (Figure 3).

The wood borings of *Platypus* normally are composed of long sliver-like particles; however, they may be of irregular shape in the case of trees that have been dead for several years in which the wood is brittle. The borings

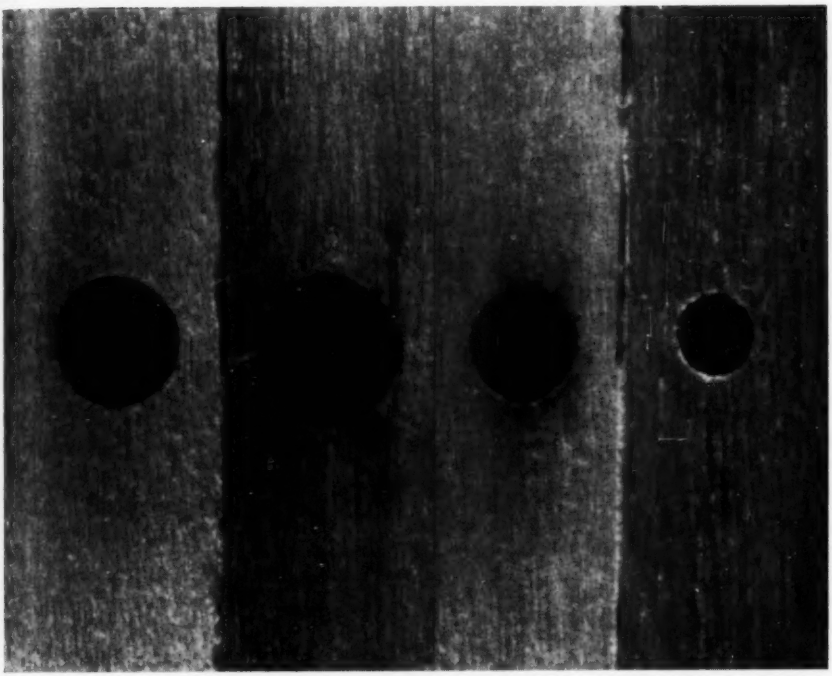

Fig. 4. Cross-section of tunnels of ambrosia beetles. Left to right: *Platypus, Trypodendron, Gnathotrichus* (in hemlock) and *Xyleborus* (in alder). (X9)

produced by *Gnathotrichus* are chiefly C-shaped shavings; whereas those of *Trypodendron* are of variable shape with ragged edges. The boring particles of *Xyleborus* are similar in shape to those of *Trypodendron,* but are smaller and tend to cling together more.

Diameter of Tunnel

If the insect itself is not present and the boring dust has been washed from the log, one can identify the genus doing the damage by the diameter of the circular tunnel (Figure 4). The galleries constructed by these insects vary in size, but the variation within genus is less than that between genera.

Platypus has an intermediate size gallery measuring 0.057 inch. *Trypodendron* galleries measure the largest or 0.064 inches in diameter. Gnathotrichus measures 0.052 inch, and *Xyleborus* measures 0.035. These values are based on measurements made on galleries with wire gauge drills.

A gauge for gallery size can be fabricated from a dissecting needle cut off squarely so that the end is 0.057 inches in diameter. This single gauge serves nicely to distinguish the galleries of the subject ambrosia beetles. It just barely fits a *Platypus* gallery, fits loosely in *Trypodendron* galleries; and is too large for *Gnathotrichus* galleries. The small *Xyleborus* galleries can be distinguished visually. All gauging was correct except for 20 per cent of the *Gnathotrichus* cases which because of soft wood or saprot were confused with *Platypus.*

The pattern of galleries as illustrated by Prebble and Graham, (1957), can be used to distinguish the genera of ambrosia beetles where complete galleries can be obtained. Habits of the insect are helpful as distinguishing the genera also: *Platypus wilsoni* very seldom attacks Douglas-Fir. *Trypodendron* attacks earliest in the spring. *Xyleborus* rarely occurs in conifers in this area but can occasionally be found in red alder, madrone, and other broadleafed trees. On Vancouver Island, however, Prebble and Graham, (1957), report that this species occasionally attacks hemlock logs at intensities up to six attacks per square foot of log surface.

The guides are proposed for ready field identification of ambrosia beetles of common occurrence in the Douglas-fir Region. Correct identification should facilitate the reporting of damage by ambrosia beetles, and encourage needed studies of their economic importance in the Pacific Northwest.

Summary

Five species of ambrosia beetles that attack coniferous timber in the Douglas-Fir Region are: (1) *Platypus wilsoni* Swaine, (2) *Trypodendron lineatum* Oliver, (3) *Gnathotrichus sulcatus* Leconte, (4) *G retusus* Leconte, and (5) *Xyleborus saxeseni* Ratz. Although little has been reported on their economic significance in western United States, they undoubtedly cause degrading losses in high quality logs left in the woods for extended periods. The frequency of occurrence, the intensity of attack, and the resulting damage differs with the species of ambrosia beetle. It is therefore desirable to be able to identify the agent causing the damage. This paper provides a means for identifying the more important ambrosia beetles in this region by the body shape of the insect, the diameter of the tunnel constructed and the character of the wood borings ejected from the tunnels.

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Production of Apterous and Alate Progeny by Apterous and Alate Viviparae of *Macrosiphum solanifolii* (Ashm.) (Homoptera: Aphididae)[1]

By M. E. MacGillivray and G. B. Anderson[2]
Field Crop Insect Section
Entomology Laboratory, Fredericton, N.B.

Factors promoting wing production in aphids have been studied extensively by many workers (Ackerman, 1926; Bonnemaison, 1951; Ewing, 1925, 1926; Lal, 1952, 1955; Shull, 1926-1942; Wadley, 1923; and White, 1946), who advanced theories based on experimental results with different species but generally considered to be applicable to all aphids. Lal (1952, 1953) reviewed this literature. The experiment reported here indicates that the theories previously advanced do not apply equally to all species.

Four potato-infesting species of aphids, *Macrosiphum solanifolii* (Ashm.), *Aulacorthum solani* (Kltb.), *Aphis abbreviata* Patch, and *Myzus persicae* (Sulz.) have been reared continuously in the greenhouse at Fredericton, N.B. since 1953 (MacGillivray, 1955). Only *M. solanifolii* has produced alate forms in abundance during this period. Alatae of *A. solani* have never been produced although the potatoes on which they were reared became crowded and the leaves twisted as a result of the feeding of the colonies. *A. abbreviata* has typically produced alate forms at two periods each year, in April and May, and from August to November, usually in association with the production of males, indicating that these winged females are gynoparae. Alate forms of *M. persicae* have been observed when the host plants were heavily populated.

Shull (1929), working with *M. solanifolii* (Ashm.), concluded that certain conditions of light and temperature promoted the production of alatae in this species and that whether an aphid was to have wings was determined within the last two days before birth. His experiments indicated that a high percentage of alate offspring were produced when the aphids were exposed to starvation during a period of darkness, or to eight hours of light alternated with 16 hours of darkness at temperatures not over 20°C. Shull (1935) showed that strains of *M. solanifolii* may respond differently, but that generally alate offspring became less numerous as the parents grew older and that apterous parents had a greater tendency to produce alate progeny than did alate parents.

This is a report on an experiment on the role of parentage in the production of winged offspring conducted in the greenhouse between April 7 and August 13, 1953. The four potato-infesting species were reared at the same time, in the same greenhouse chamber. Only *M. solanifolii* produced alate aphids. The following data concern *M. solanifolii*.

Methods

The aphids were reared on excised leaves of Katahdin potato covered with an organdy cylinder cage (MacGillivray and Anderson, 1957) in a greenhouse chamber under alternating periods of six hours of darkness and 18 hours of light. Natural daylight was supplemented by two fluorescent lights, 120 watts each, placed three feet above the cages. Temperature varied but was usually 70°F.

Nineteen series of aphids were reared between April and August. For each series five first-instar nymphs born of a known type of parent (apterous or

1Contribution No. 3677, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.

2Associate Entomologist and Assistant Technician.

TABLE I

Percentages of apterous offspring produced by alate and apterous viviparae of *M. solanifolii* of various ancestries

Ancestry and type of parent	Apterous offspring, %	Number in test		Date birth to death	Average temperature, °F.
		Parents	Offspring		
O–X–O–X–O–X[1]	100	1	63	June 23–Aug. 3	70
X–X–X–O	100	5	302	May 26–July 9	71
X–O–O–O–X–O	99.5	5	236	June 23–Aug. 13	70
X–X–X–O–O–O	98	5	296	June 23–Aug. 13	71
X–X–O–O–O–X	98	4	195	June 9–July 20	70
X–O	98	4	173	Apr. 8–May 16	77
O–X–O–X–X–O	98	5	278	June 25–Aug. 13	71
O–X–O–X	97	5	283	May 21–July 3	69
O–X–O–X–O–O	96	4	229	June 23–Aug. 8	70
X–X–O–O–X–O	95	5	313	June 23–Aug. 6	70
O–X–X–O–X–O	94	5	258	June 25–Aug. 6	70
X–X–O–X	94	1	56	May 21–June 29	69
X–X–O–X–O–X	89	1	55	June 24–Aug. 8	70
O–X–X–O–O–X	85	4	178	June 23–Aug. 6	70
X–O–O–O–O–X	84	4	194	June 23–Aug. 8	70
O–X–X–O–O–O	84	1	64	June 23–Aug. 4	70
X–O	83	1	79	Apr. 15–May 20	73
X–X	82	3	116	Apr. 15–June 8	72
X–O–O–O	79	4	257	June 4–July 13	70
O–X	78	4	207	Apr. 15–June 3	72
O–X–X–O	76	5	305	May 17–July 12	71
X–X–O–O	72	4	215	May 21–June 29	69
O–O	72	1	43	Apr. 7–May 10	79
X–X–O–X–O–O	71	4	322	June 24–Aug. 10	71
X–X	67	1	94	Apr. 8–May 15	77
O–X	66	4	206	Apr. 7–May 10	79
X–O–O–O–O–O	54	1	46	June 23–July 12	71
O–O	33	1	90	Apr. 15–May 8	74

[1]Forms of successive ancestors, the last symbol being that of the parent producing the recorded percentage; O, apterous; X, alate.

alate) were each reared from birth to death on individual leaves. When these nymphs matured, some or all were winged and some or all were wingless. The number of young that these forms produced daily was recorded and each day's complement of offspring of all alate parents was transferred to a single leaf and those of the apterous parents to another leaf; i.e., two leaves were used for the offspring in each series for each day of the reproductive period. The alate or apterous condition of these offspring was recorded as they in turn matured. The parents used to obtain the five nymphs for each series were produced in a previous series on the tenth day of reproduction of their parents, which is the middle of the reproductive period (MacGillivray and Anderson, 1958). During the experiment 92 aphids and their progeny were reared.

Results

Table I shows that in general a greater percentage of apterous forms were produced regardless of the type of parent. Table I does not show that the progenitors of the parent influenced the type of offspring.

In the 19 series reared between April and August, the ratio of apterous to alate offspring produced by alate parents was 7:1; by apterous parents, 6:1. Between July 23 and August 13, when there was less variation in temperature (average temperature 71°), alate parents produced apterous and alate offspring in the ratio of 14:1; apterous parents, in the ratio of 13.6:1. In both cases a chi-square test showed that the type of parent and the type of offspring were independent ($P < 0.5$).

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TABLE II

Percentages of apterous offspring produced by apterous and alate sister viviparae of *M. solanifolii* of various ancestries

Ancestry	Apterous sisters		Alate sisters	
	Number	Apterous offspring, %	Number	Apterous offspring, %
X-X-O-X-O[1]	4	71	1	89
O-X-O-X-O	4	96.0	1	100.0
O-X-X-O-O	1	84	4	85
X-O-O-O-O	1	54	4	84

(1) Forms of successive ancestors: X, alateï O, apterous.

Table II shows that apterous parents always produced a smaller percentage of apterous offspring than did their alate sisters. Transforming the percentages to arc-sines and using a chi-square test showed that the difference was significant ($P < 0.05$).

Alate forms were not always produced continuously during the reproductive period of either type of parent, but sometimes on widely separated days. When a parent produced a mixture of alate and apterous offspring the peak in numbers of alatae consistently followed that of apterae. Alate parents produced the greatest number of alate offspring on the ninth day of reproduction, or about three days after the greatest number of opterae was produced (Fig. 1). The number of alatae produced by some of the parents at that time was greater than the number of apterae produced. Apterous parents produced the greatest number of alate offspring on the third, sixth and eleventh days of reproduction. These peaks followed by one to three days the peaks of production of apterous offspring (Fig. 2).

Discussion

As only *M. solanifolii* produced winged forms in the experiment, the four potato-infesting species apparently do not require the same factors to induce wing development, or if the same factors are concerned they must be required in different degrees. However, during the experiment five apterae and one

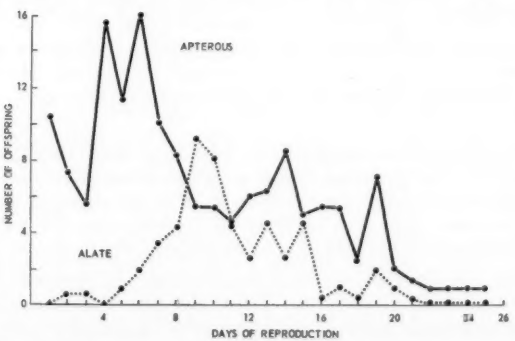

Fig. 1. Average daily numbers of alate and apterous progeny produced by 11 alate females of *M. solanifolii*.

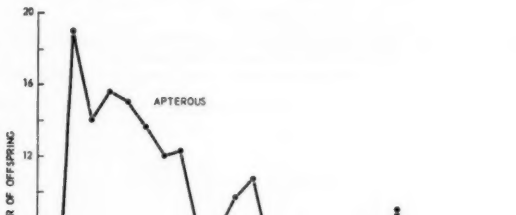

Fig. 2. Average daily numbers of alate and apterous progeny produced by 11 apterous females of *M. solanifolii*.

alata of *M. solanifolii* produced only apterae, and when alatae were produced they were generally fewer than apterae. This would be expected since Shull (1929) found that *M. solanifolii* usually produced few alatae when periods of darkness were less than 10 hours and the temperature exceeded 20°C.

Although Shull (1935) found that apterous parents of *M. solanifolii* tended to produce more alate offspring than did alate parents, in these experiments apterous parents produced apterae and alatae in about the same ratio as did alate parents. However, the alate or apterous condition of parents that are sisters seems to influence the percentage of apterous progeny since alate sisters always produced a higher percentage of apterous offspring than did their apterous sisters.

Shull (1935) found that among parents of *M. solanifolii* kept under uniform conditions before and during reproduction the number of winged offspring rapidly and steadily declined from the beginning to the end of reproduction and that the decline was more rapid for apterous parents than for alate ones. Also, at a high temperature (75°F.) and in continuous light the age of the parent was the chief factor governing distribution of wing production through its family. In the present experiment, where alatae were produced continuously there were peaks of production of alatae by both apterous and alate parents, contrary to Shull's findings. A decline in the total number of alate offspring as well as in apterous ones would be expected as the parents grow older since MacGillivray and Anderson (1958) have shown that the number of offspring produced daily by alatae normally decreases after five days and by apterae after nine days of reproduction. This may explain the decline in the number of winged offspring noted by Shull.

Although factors such as temperature, length of daylight, and the condition of the host possibly influence the peaks of production of alate offspring, such factors are not likely to have been active in the present experiment. Among parents of a single series only the condition of the host may have varied, although care was taken to select leaves of the same age and of a healthy appearance.

Some authors (Ackerman, 1926; Bonnemaison, 1951) have considered that crowding was the cause, directly or indirectly, for the development of alate aphids. Their conclusions were largely based on studies of colonies or groups of parents. In the present experiment the parents were isolated from birth to death and were therefore not affected by crowding. The production of alate

forms observed by other workers when the plants became crowded may not have been due to the crowding. The crowding may have occurred after the first ten days of reproduction, when the greatest numbers of both forms are produced, but the alatae might have occurred whether the crowding existed or not. To relate the presence of alatae of *M. solanifolii* to crowding does not seem justified, since alate forms were produced by uncrowded parents during the peak of reproduction after the peak of production of apterae. This may also apply to populations of *M. solanifolii* out-of-doors when wing development occurs after the highest recorded populations for the season. Furthermore, these experiments suggest that, at least with *M. solanifolii*, any study of wing development must be based on individual aphids of a known age, rather than on colonies of aphids that may be of various ages and in various stages of development.

Summary

Of four potato-infesting aphids reared under the same experimental conditions in the greenhouse between April and August, only *M. solanifolii* (Ashm.) produced alate forms, although apterous offspring were usually more numerous than alate offspring. Apterous and alate parents produced about the same percentage of apterous offspring. Alate sister aphids produced a higher percentage of apterous progeny than did their apterous sisters. The greatest number of alate offspring was produced a few days after the greatest number of apterous offspring had been produced and did not occur as a result of crowding. Any study of wing development in this species should be based on individual aphids of a known age.

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(Received June 3, 1957)

A Sectional Insectary Structurally Adaptable to Changing Requirements[1]

By C. F. NICHOLLS[2]
Entomology Laboratory, Belleville, Ontario

Requirements for insectaries or screened enclosures vary in entomological field work. Consequently a sectional insectary structurally adaptable to meet many requirements would have many uses. Recently such a structure was developed at the Belleville laboratory. Its design and construction are described in this paper and data are included on a number of insectaries that may be erected from a given number of similar parts.

Figure 1 indicates the method of construction used. This insectary is 12 feet square by 9 feet high and consists of 32 equal sections. Thirty-one are screened and one contains a door. Each screened section (Fig. 2) is composed of an aluminum frame (C), a piece of screen (B), and a wooden frame (A). The aluminum frame is made of 1½-inch-by-2¼-inch extruded angle (Dexion [Canada] Ltd., Weston, Ontario). It is 6 feet long by 3 feet wide by 1½ inches thick, with the corners mitred and welded. The screening is 20-mesh natural coloured saran (Chicopee Mfg. Corporation, N.Y. 13, N.Y.). It is stapled to the wooden frame. The wooden frame is made of strips 9/16 inch by ¾ inch.

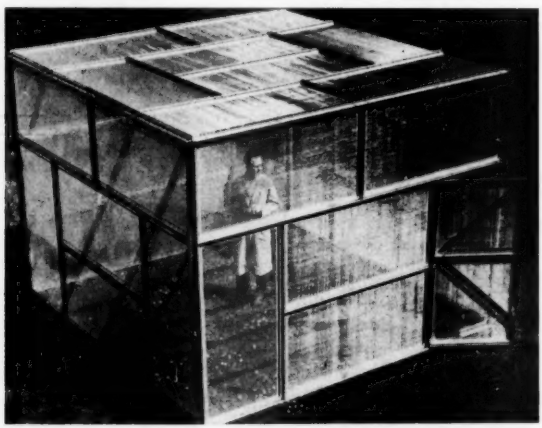


Fig. 1. Insectary showing one arrangement of sections.

It is 5 feet 10¾ inches long by 2 feet 10¾ inches wide by 9/16 inch thick. In assembling the section the screen and the wooden frame are first fastened together. They are then attached to the aluminum frame with brass wood screws. Sections may be paneled with some form of fibreboard.

The door section consists of an aluminum frame (Fig. 2, C) and a door. The door is 5 feet 10¾ inches high by 2 feet 10¾ inches wide by 1½ inches thick. Braces are used to add rigidity. Three butt hinges are used to hang the door within the aluminum frame. Three brass bolts with wing nuts are fixed to the aluminum frame, each opposite a hinge and facing a corresponding hole

1Contribution No. 3690, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.
2Technician.

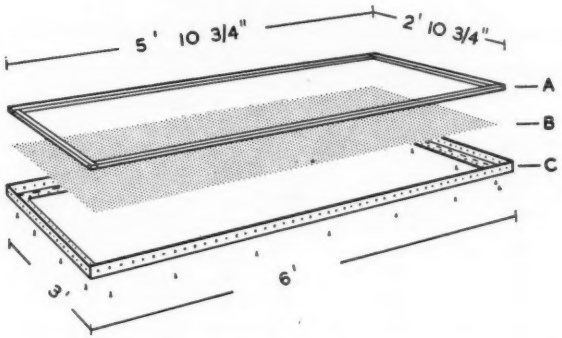


Fig. 2. The components of a screened section.

in the door. They are used to tighten the door from the outside against a sponge-rubber gasket. A casement sash fastener is used as an inside catch.

The sections are arranged (Fig. 1) to give maximum rigidity to the structure. They are attached from the outside with galvanized bolts 5/16 inch by ¾ inch. Those that form corners are bolted to inserts (pieces of aluminum angle, Fig. 3, D, E, F). The inserts consist of 6-foot and 3-foot lengths. Two men can erect this structure in a few hours. The insectary shown in Fig. 1 weighs approximately 300 pounds, each section weighing only 7½ pounds. Consequently it may be necessary in some exposed, windy, situations to attach guy wires.

Insectaries of many sizes and shapes can be erected from a given number of sections. Table I shows data on those that can be made from 42 sections, including seven door sections, which are necessary to equip the maximum number of small insectaries with doors. In some cases it may be necessary to use a door section in place of a screened section. One or more posts are needed to support the roofs of large insectaries. These are made of the same material as is used in the aluminum frames.

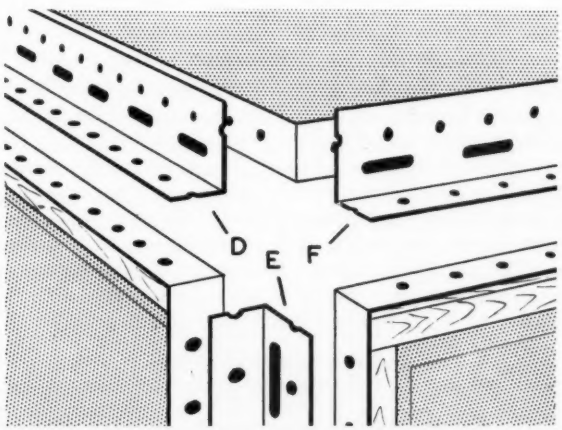


Fig. 3. Details of corner construction.

TABLE I
Sizes and shapes of 36 insectaries that can be assembled from 35 screened sections, 7 door sections, and other accessories

Size of insectary feet			Number of parts needed			
			Sections, total	Corner inserts		Bolts max.
Length	Width	Height		6 feet	3 feet	
18	18	6	42	24	8	504
18	18	3	30	16	20	360
18	15	6	37	20	12	444
18	12	9	42	24	4	504
18	12	6	32	16	16	384
18	12	3	22	14	16	264
18	9	6	27	16	12	324
18	6	12	38	20	16	456
18	6	9	30	16	12	360
18	6	6	22	14	8	264
18	6	3	14	8	8	168
18	3	12	31	16	12	372
18	3	6	17	12	12	204
15	12	6	28	16	12	336
15	6	12	33	16	12	396
15	6	6	19	12	12	228
12	12	12	40	16	16	480
12	12	9	32	16	12	384
12	12	6	24	12	16	280
12	12	3	16	12	12	192
12	9	12	34	16	12	408
12	9	6	20	12	12	250
12	6	12	28	16	8	336
12	6	9	22	12	12	264
12	6	6	16	12	8	192
12	6	3	10	8	8	120
12	3	12	22	12	12	264
12	3	6	12	8	12	144
9	6	12	23	12	12	276
9	6	6	13	8	12	176
6	6	12	18	12	8	216
6	6	9	14	8	12	168
6	6	6	10	8	8	120
6	6	3	6	4	4	72
6	3	12	13	8	12	156
6	3	6	7	4	6	84

An insectary of this type has many advantages over other kinds. It is easily dismantled and can be reassembled with a minimum of help and tools. Moreover, it can be used in a number of different ways and provides the components for insectaries of many other sizes and shapes. It can be readily transported. As it is light in weight it can be carried on top of a passenger car, in a small boat, or even by hand into almost inaccessible places. The materials used are durable. The Saran screening permits nearly natural conditions to be maintained within the enclosure. On the other hand, interchangeable fibreboard panels would provide some protection from the weather when necessary. Although it is relatively expensive to build this is offset by its great versatility.

(Received September 4, 1957)

Far-eastern Pyralidae (Lepidoptera)[1]

By EUGENE MUNROE[2]
Insect Systematics and Biological Control Unit
Entomology Division, Ottawa, Canada

Through the kindness of Dr. H. Höne, Bonn, I have the privilege of examining a large number of Pyralidae collected by him in China and Japan during his many years' residence in those countries. The material studied consists of duplicates of the vast collections sent to Prince Aristide Caradja in Rumania, and reported on by him in an extended series of papers in the years 1925 to 1939. In spite of his excellent taxonomic eye, Caradja did not study genitalia and rarely illustrated his species or discussed their structural characters. As Höne's collections have been the only ones to emanate from many of the regions he visited, and as Caradja's own collection, always remote, has for many years been inaccessible, and is believed to have been partly destroyed in wartime or post-war disturbances, the importance of the present material in elucidating the Caradja species is very great, and I owe Dr. Höne my most sincere thanks for permitting me to study it and to retain for the Canadian National Collection a substantial number of duplicates.

The exigencies of preparation and return of the material make it preferable to publish descriptions and notes as individual species are studied, rather than to wait until a comprehensive study in systematic order is possible. Extensive species lists for the localities have already been published by Caradja, and most, if not all, of the species included in the present collection were seen by him. The novelties here reported are therefore mainly of four kinds: description of new species or subspecies not differentiated by Caradja from their allies, correction of misidentifications, establishment of new synonymy, and revision of generic placements. I shall also take the opportunity to illustrate a number of Caradja's species, even where no change of classification is necessary. I have been able to examine in addition to the Höne material considerable material from Japan, Manchuria, the Amur-Ussuri regions, China and Tibet, and this also is discussed where appropriate. In certain groups it has not been possible to separate the discussion of Far-eastern forms from those of their European, American or tropical allies; consequently some notes on extralimital taxa will appear in this series.

Sinomphisa, new genus
Type species: *Pionea* (?) *plagialis* Wileman

Frons flat and oblique; maxillary palpus not very long, its tip dilated with scales; labial palpus long and slender, porrect or somewhat decurved, the third joint distinguishable, though basally enveloped in the hair-like scales of the second; antenna filiform and ciliated in both sexes; body moderately robust; legs with outer tibial spurs somewhat reduced. Wings of moderate proportions, with outer margins almost evenly rounded. Fore wing with cell about half its length; R_1 from near apex of cell; R_2 from very near apex; R_5 strongly approximated to R_{3+4}; M_1 from upper angle of cell; discocellular concave outward, moderately oblique; M_2, M_3 and Cu_1 from lower angle of cell, M_2 and M_3 strongly, M_3 and Cu_1 weakly, approximated; Cu_2 from cell at four-fifths; anal loop large and complete. Hind wing with Sc and R_s anastomosing very briefly; M_1 from upper angle of cell; cell short; discocellular weakly oblique, weakly bent on median

1Contribution No. 3656, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.
2Senior Entomologist.

fold; M_2, M_3 and Cu_1 arising from lower angle of cell; M_2 and M_3 weakly, M_3 and Cu_1 strongly, approximated; Cu_2 arising very close to end of cell.

Male genitalia. Saccus long; vinculum and tegumen broad; uncus slender, the basal part arched dorsad, the apex weakly dilated and dorsally spinose. Valve broadly rounded, costa narrowly, sacculus more widely, inflated; a broad, somewhat flattened and irregular harpe on inner face. Penis slender, curved at extreme base, one side sclerotized; one long moderately slender cornutus and a dense group of very small ones.

The single species of this genus is not related to *Pionea*, nor does it fit well in *Omphisa* Lederer, where Caradja placed it. The new genus differs from *Omphisa* in the more slender build, in the less angulate wings, in the flat, not rounded, frons, in the strong, not weak, approximation of R_5 to R_{3+4}, in the origin of Cu_2 of hind wing near the end of the cell, not well before it, and in various characters of the genitalia, such as the long slender penis, with strong cornuti, not thick and unarmed as in *Omphisa*, and the slender arched uncus, opposed to the short spatulate one of *Omphisa*.

Sinomphisa appears to be more closely related to *Pachynoa* Lederer and *Ghesquierellana* Berger than to *Omphisa*. For the present I include in *Pachynoa* in addition to *thoosalis* Walker, the type, such species as *pectinicornis* Gn., *sabelialis* Gn. and *purpuralis* Wlk., which agree in having a strongly angled discocellular and in the male bipectinate antennae and a thorn-like process on the dorsal surface of the hind wing near the end of the cell. The type of *Pitacanda*, viz., *spilosomoides* Moore, shares this unusual combination of external characters, and for the time being may be left in *Pachynoa*, though the genitalic specializations, particularly the hypertrophy of the uncus, may necessitate a separation when a full range of species is studied. *Ghesquierellana*, with type *pallas* Meyrick, is obviously related to *Pachynoa*, but lacks the three specializations mentioned in connection with that genus: the discocellular of the hind wing is moderately bent, the male antenna is at most laminate, and the wing-membrane is normal. *Ghesquierellana* differs from the genera discussed in having a broad carina of scales on the ventral surface of the labial palpus, much as in the *Phostria* complex. *Botys hirtusalis* Walker, placed by Hampson in *Botyodes*, is, if the Central and West African material before me is correctly identified, very close to or identical with *pallas*, and will become *Ghesquierellana hirtusalis*, new combination. *Aphytoceros* Meyrick, type *lucusalis* Walker, is closer to *Pachynoa*, and shares with it the bent discocellular. However, it lacks the specializations of male antenna and wing, and has more primitive genitalia, and will, I think, prove separable.

***Sinomphisa plagialis* (Wileman), new combination**

Figs. 1, 4

Pionea (?) *plagialis* Wileman, 1911: 387, Pl. 31, Fig. 10.
Omphisa albalis Caradja, 1925: 99, Pl. 2, Fig. 53.
Omphisa plagialis Caradja, 1932: 153.

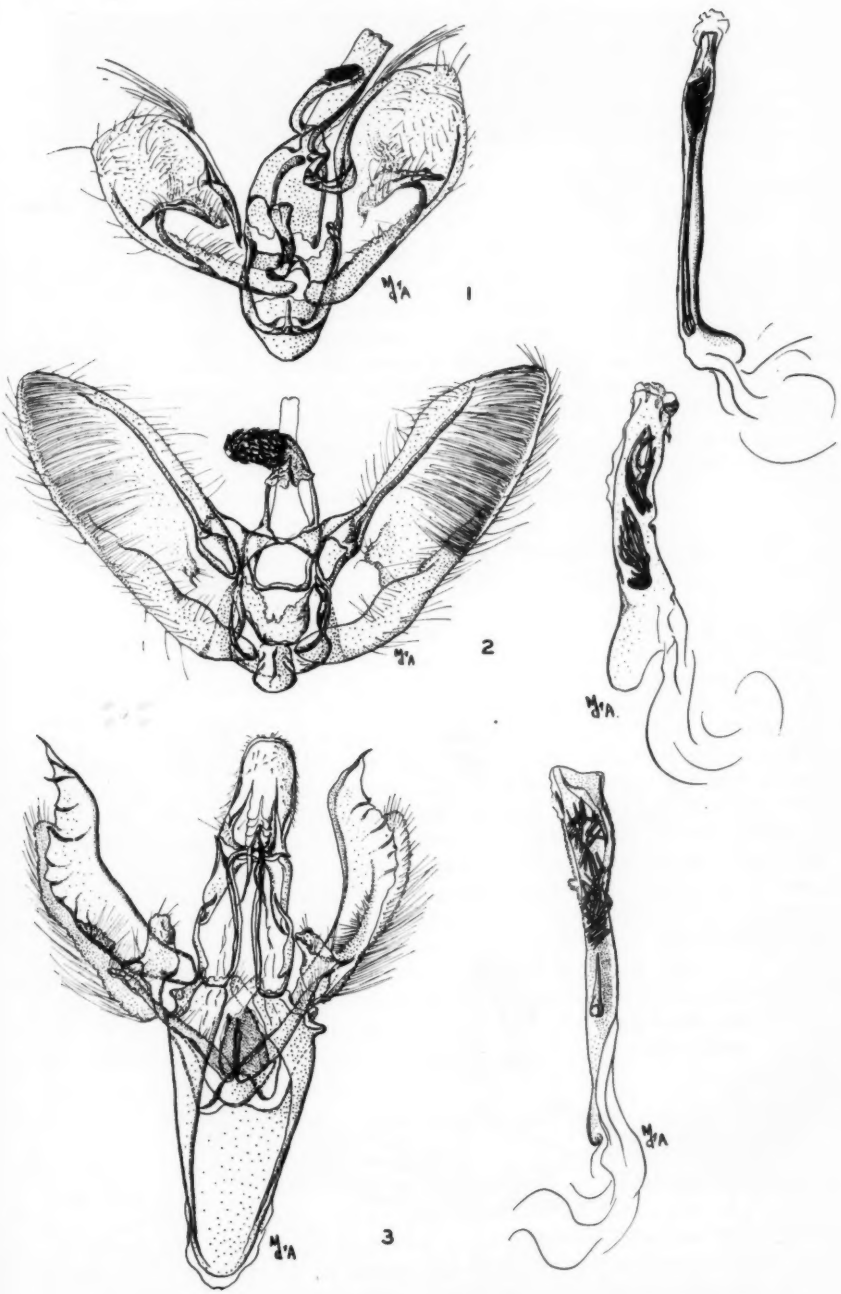
I can see no difference between Chinese and Japanese specimens. Caradja has already established the specific synonymy, but his paper is obscure and the names remain separate in many collections.

***Proteuclasta*, new genus**

Type species: *Proteuclasta stötzneri* (Caradja), new combination = *Pyrausta* (?) *stötzneri* Caradja

Figs. 2, 5, 7

Characters of *Euclasta*, except that the antenna is of normal proportions, i.e., shorter than the fore wing, not appreciably longer as in *Euclasta*, and the labial



Figs. 1-3, male genitalia.
1, *Sinomphisa plagialis*. 2, *Proteuclasta stötzneri*. 3, *Dioryctria magnifica*.

Figs. 4-6, genitalia.
4, *Sinomphisa plagialis*, ♀. 5, *Proteuclasta stötzneri*, ♀. 6, *Pyradena mirifica*, ♂.

Figs. 7-9.

7, *Proteuclasta stötzneri*, ♂. 8, *Pyradena mirifica*, ♂. 9, *Dioryctria magnifica*, ♂, paratype.

palpus is porrect, exceeding the head by more than its length. Genitalia as in *Euclasta*. The genus *Euclasta* itself varies somewhat in external structure: some species have the antenna annulated with scales, whereas it is smooth in others, including the type; also, the labial palpus varies in length, being long and porrect in the otherwise normal *Euclasta warreni* Distant. However, all species of *Euclasta* I have examined agree in having the antenna abnormally long, and I regard the combination of long palpus and short antenna as having generic value.

Caradja was aware of the resemblance to *Euclasta*, but was uncertain whether or not it was due to parallelism. The genitalia of both sexes are closely similar to those of *Euclasta* and there is evidently a direct relationship.

***Pyradena*, new genus**

Type species: *Pyradena mirifica* (Caradja), new combination = *Adena mirifica* Caradja

Figs. 6, 8

Frons rounded, moderately protuberant; antenna laminate; labial palpus long and porrect; maxillary palpus with an expanded distal tuft of scales. Fore wing with apex acute; costa arched, distal margin strongly produced behind Cu_2, excised before and behind; R_1 and R_2 free; R_5 not approximated to R_3+_4, M_1 from below apex of cell; lower angle of cell weakly produced; M_2 and M_3 arising close together at end of cell, Cu_1 just before end of cell, Cu_2 well before end of cell. Hind wing with margin very weakly undulated; Sc and R_s well anastomosed; lower part of discocellular strongly oblique, lower angle of cell acute; M_2, M_3 and Cu_1 arising from angle, M_2 and M_3 approximated in basal parts.

Male genitalia: tegumen short, broad, bilobed; uncus fairly broad, rostriform, with parallel sides and rounded tip, the distal part armed with anteriorly directed spines; gnathos a narrow band, arcuate in middle; juxta rather large, dorsally emarginate; valve rather long, curved dorsad, with a rounded tip; a strong subcostal spur; sacculus inflated at base; penis small, of irregular shape.

This genus differs externally from *Adena* chiefly in the close crowding of the veins at the posterior angle of the fore-wing cell; the strongly divergent male genitalia show that the relationship of the two genera is not very close.

Only the type species is known.

***Dioryctria magnifica*, new species**

Figs. 3, 9

Phycita splendidella Caradja, 1938: 107; err. det.

Maxillary palpus filiform in both sexes, fore wing with only faint indications of raised scale ridges. General appearance somewhat similar to that of *D. splendidella*, but with reddish shades on medial and subterminal fields and with darker hind wing. Ground colour of fore wing dark grey, heavily powdered with blackish in basal half and beyond cell. Prominent chestnut-brown suffusion in basal area, especially on posterior half; traces of brown below end of cell; a band of somewhat redder brown beyond postmedial line. A diffuse black spot on M

just beyond base; a nearly vertical subbasal line, bent slightly distad towards inner margin, blackish, with a faint pale-grey border on basal side; antemedial line very slightly oblique, from costa at two-fifths to inner margin just before middle, excurved in cell and below it and oblique outward below 2nd A, the three sections marked off by inward angulations on Cu and 2nd A; the line light grey, bordered weakly basad and strongly distad with blackish; an indistinct, erect, pale-grey shade just beyond antemedial line, beginning behind costa and ending in front of inner margin; a diffuse blackish shade on inner margin behind it and extending obliquely costad beyond it; a pale-grey, oblique, ovate discocellular spot; postmedial line blackish followed by pale grey, continuous, angled obtusely distad at M_2, weakly incurved before and behind the angulation; short black streaks intersecting the dark element of postmedial line along the veins; weak dark streaks along veins in subterminal area; a black terminal line. Fringe grey, with two darker lines. Hind wing translucent, fairly dark grey, veins and margins darker; fringe grey with a darker line near base. Under side light grey with fuscous veins and margins; most of fore wing and costa and outer margin of hind wing suffused with dark grey; fore wing with a pale discocellular spot and traces of a dark postmedial line, with faint, pale, distal shading near inner margin; hind wing with a trace of pale postmedial line on anterior half. Both wings with a narrow, dark, terminal line; fringes as above.

Male genitalia strikingly different from those of *D. splendidella* (as figured by Standfuss, 1914), more closely resembling those of some of the American species of the genus. Uncus almost parallel-sided and with apex subtruncate; valve with sclerotized part acute-tipped, falcate, with posterior margin pleated; membranous part shorter than sclerotized part. Penis with about 50 smaller spines and one large one.

Holotype, male, and eight paratypes, Tapaishan in Tsinling, S. Shensi, China, June 21 to July 2, 1935, H. Höne. Holotype and five paratypes in Museum Koenig, Bonn; the remaining paratypes No. 6580, in the C.N.C.

Acknowledgments

I am indebted to Dr. H. Höne for making this fine material available. The drawings were made by Miss M. d'Aoust.

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(Received June 24, 1957)

Studies of the Byron Bog in Southwestern Ontario. V. Seasonal Distribution of Horseflies and Deerflies (Tabanidae)[1]

By W. W. JUDD[2]

In the description of the Byron Bog (Judd, 1957) it was pointed out that one method of collecting insects in the bog was the use of a trap baited with malt extract and the position of the trap in the bog was also shown. The construction and use of the trap are described by Judd (1956). The trap was in operation from May 15 to November 15, 1956 and insects were removed from the trap each day and counted. Among the insects so collected were horseflies and deerflies. In addition, four of these flies were collected by making a circular sweep with an insect net, held at arm's length, through the tops of the bushes in the *Chamaedaphnetum calyculatae* association (Judd, 1957). The net used was one with a rim twelve inches in diameter and the radius of the circle over which the sweep was made was six feet. A single sweep was made each day from May 15 to November 15, 1956 and the flies so collected were sorted and counted.

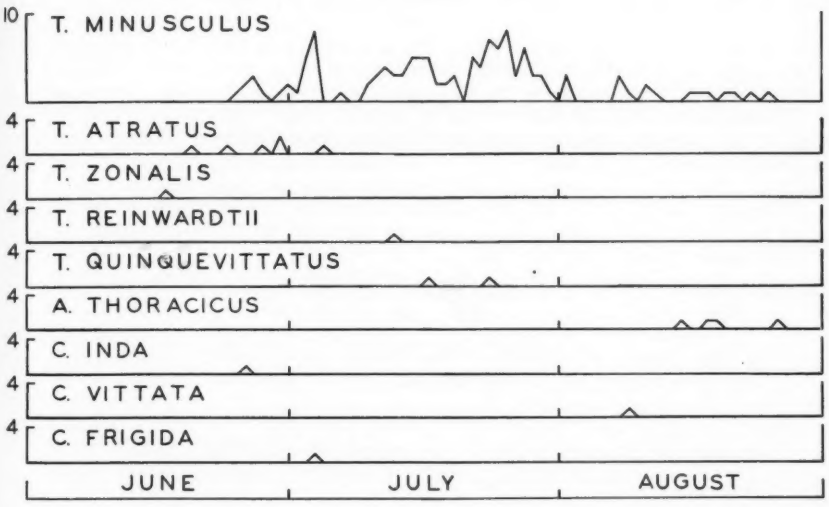

Figure 1

The flies were identified by Dr. L. L. Pechuman, Lockeport, New York who retained for his collection specimens of *Tabanus minusculus* Hine (5 ♂ ♂, 5 ♀ ♀) and *Atylotus thoracicus* (Hine) (1 ♂, 1 ♀). All other specimens are retained in the collection of the Department of Zoology, University of Western Ontario. All the species collected have been previously recorded from Ontario (Brennan, 1935; Philip, 1947, 1949; Stone, 1930, 1938) and Michigan (Hays, 1956). The distribution of the flies through the season in the Byron Bog is shown in Fig. 1.

Account of Collections

Tabanus minusculus Hine—72 ♂ ♂, 53 ♀ ♀ (June 25-August 25). Males were caught first on June 25 and females first on July 1. Two females were

1 Contribution from the Department of Zoology, University of Western Ontario; a project supported by funds from the government of Ontario granted through the Ontario Research Foundation.

2 Associate Professor Zoology; the collections were made and the data assembled while the writer held a Summer Research Associateship of the National Research Council in 1956 and 1957.

caught by sweeping on July 3 and July 28. Stone (1930) collected a larva in sphagnum moss in a bag in New York State and Pechuman (*in litt.*) reported that he had never collected this species except in sphagnum bogs.

Tabanus atratus Fab.—1 ♂ (June 30), 5 ♀ ♀ (June 20, 24, 28, 30, July 5).
Tabanus zonalis Kirby—1 ♀ (June 17).
Tabanus reinwardtii Wied.—1 ♀ (July 13).
Tabanus quinquevittatus Wied.—1 ♂ (July 17), 1 ♀ (July 24).
Atylotus thoracicus (Hine)—2 ♂ ♂ (August 15, 26), 2 ♀ ♀ (August 18, 19).
Chrysops inda Osten Sacken—1 ♀ (June 26) caught by sweeping.
Chrysops vittata Wied.—1 ♀ (August 9) caught by sweeping.
Chrysops frigida Osten Sacken—1 ♂ (July 4).

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(Received June 19, 1957)

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